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THE EFFECTS OF FROST DAMAGE ON THE NUTRITIONAL VALUE OF WHEAT

II. FEEDING TESTS ON VARIOUS MILL FRACTIONS

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ABSTRACT

Frost-damaged and high quality wheats, weighing 28 and 63 lb. per bushel, respectively, were milled and the patent, clear and red dog flours, the shorts and the bran were used in feeding trials with mice in a factorially designed experiment. Three levels of a multiple B-vitamin supplement were added (0, 25 and 50 per cent of the dietary requirements of the mouse) and the mill fractions were compared (a) directly as the major ingredients in rations containing 16 per cent protein; (b) in rations standardized to contain 7 per cent cellulose, and (c) in rations having *wet bulk* standardized.

No deleterious effects of severe pre-harvest frost damage on the major mill fractions were revealed. Frozen wheat fractions proved to be superior to those from control samples in this test. It was concluded that the reduced feeding value of frozen wheat weighing less than about 45 lb. per bushel could be attributed mainly to the preponderance of bran and shorts, as opposed to endosperm, which reduced the amount of available energy per unit weight of wheat and in part to certain peculiar and yet unexplained effects of ration density which influenced feed capacity of the animals.

INTRODUCTION

Previous studies (1) revealed no important nutritional changes, other than in energy content, in frost-damaged wheat, unless the bushel weight fell below about 45 lb. Whiting and Bezeau (9) confirmed these findings and reported that digestibility of protein was depressed in frozen wheat but was counterbalanced by increased biological value.

This report concerns feeding trials with mice on the various mill fractions of sound and severely frozen wheat samples. Special emphasis was placed on the adequacy of B-vitamins in the various regions of the kernel and upon the effects of ration bulkiness in the digestive system.

MATERIALS AND METHODS

Preparation of Wheat

Samples of cleaned, sound wheat weighing 63 lb./bu. and of cleaned, frozen wheat weighing 28 lb./bu. were milled in a laboratory flour mill and separated into the customary fractions. After recording yields, the following fractions were retained for use in feeding trials with mice: (a) patent flour; (b) clear plus red dog flour in equal proportions; (c) shorts and (d) bran.

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TABLE 1.—RATION FORMULAS USED IN MOUSE FEEDING TRIALS (AMOUNTS IN PERCENTAGES)

Ration ingredients[1]	Patent flour			Clear+red dog flour			Shorts			Bran		
	Nil	Equal fibre	Equal bulk	Nil	Equal fibre	Equal bulk	Nil	Equal fibre	Equal bulk	Nil	Equal fibre	Equal bulk
63 lb./bu. wheat												
Patent flour	91.55	84.20	61.09	–	–	–	–	–	–	–	–	–
Clear+red dog flour	–	–	–	91.76	84.76	64.64	–	–	–	–	–	–
Shorts	–	–	–	–	–	–	89.97	69.75	85.06	–	–	–
Bran	–	–	–	–	–	–	–	–	–	91.99	70.00	36.10
Vitamin-free casein	1.45	2.70	8.22	1.24	2.60	7.46	–	3.99	2.31	1.01	5.02	12.50
Starch	–	–	–	–	–	–	3.03	19.26	–	–	17.98	44.40
Sucrose	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Corn oil	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Cellulose	–	6.10	23.69	–	5.70	20.89	–	–	5.63	–	–	–
Minerals[2]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
28 lb./bu. wheat												
Patent flour	90.71	83.30	61.12	–	–	–	–	–	–	–	–	–
Clear+red dog flour	–	–	–	92.04	86.20	76.16	–	–	–	–	–	–
Shorts	–	–	–	–	–	–	76.21	69.75	45.63	–	–	–
Bran	–	–	–	–	–	–	–	–	–	86.46	70.00	30.12
Vitamin-free casein	2.29	3.50	8.68	–	1.13	4.40	–	1.51	8.47	–	3.39	12.92
Starch	–	–	–	.96	–	–	16.79	21.74	38.90	6.54	19.61	49.96
Sucrose	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Corn oil	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Cellulose	–	6.10	23.20	–	5.67	12.43	–	–	–	–	–	–
Minerals[2]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00

(1) The B-vitamin treatments were added to portions of each ration.

(2) Mineral mixture: bone meal 28, $CaCO_3$ 47, NaCl 25, KI-Ca stearate .02, $FeSO_4$ 2, $MgSO_4$ 2, $MnSO_4$ .05, and $CuSO_4$ .01 gm.

Design of the Experiment

A factorially designed feeding trial was employed which involved the four mill fractions from each of the two wheats, three cellulose treatments and three multiple B-vitamin levels. The bulk modifiers were: (a) nil, to allow direct comparisons of the various fractions within and between wheats, with and without vitamin supplementation; (b) cellulose or starch to provide a 7 per cent level of crude fibre in the wheat fraction *per se*, to more or less equalize the density or *dry bulk* characteristics; and (c) cellulose to equalize *wet bulk* or the density as it might prevail in the stomach. All diets in this latter group were adjusted to an estimated bulk coefficient value of 23, similar to shorts milled from sound wheat. Data essential for the formulation of these diets were obtained by soaking 1 to 3 grams of ground feed in 0.9 per cent NaCl for 10 minutes in a 15-ml. centrifuge tube. Following this, the sample was centrifuged at 3200 r.p.m. (R.C.F. = 2000) for 5 minutes, the supernatant liquid was drained off, and the tube with wet sample was submerged in a graduate cylinder of water to permit measurement of total displacement. After deducting the tare displacement, the 'wet' volume of the feed was obtained and the bulk coefficient was calculated as the ml./10 gm. of dry matter. While this method obviously possesses certain inherent weaknesses, it was considered to be superior to that used by Proctor and Wright (8), especially for use with feeds of very low density.

Vitamin B supplements were used to supply 0, 25 and 50 per cent of the known or estimated requirements of the mouse (10). To supply 25 and 50 per cent levels, 1.65 and 3.30 gm., respectively, of the following pre-mix were added per kgm. of mixed diet: thiamin 250 mg.; riboflavin 250 mg.; niacin 250 mg.; pantothenic acid 500 mg.; pyridoxine 250 mg.; biotin 2.5 mg.; folic acid 62.5 mg.; vitamin B_{12} 1.25 μgm.; p-aminobenzoic acid 625 mg.; choline 6.25 g.; inositol 12.5 gm., and corn starch 18.58 gm.

All rations (Table 1) were modified by the addition of starch and/or vitamin-free casein to provide 16 per cent protein levels. In order to standardize palatability and texture to some extent each ration contained 1 per cent sucrose and 3 per cent corn oil. A complex mineral mixture and adequate supplements of vitamins A and D also were added. All ingredients of the rations were ground sufficiently fine to discourage sorting by the mice.

Animals and Management

Male mice of Carworth Farms No. 1 strain and weighing initially 7.5 to 8.5 grams were allotted at random to individual cages and to diets. Four replications were made on the patent flour, shorts, and bran diets but only two were made on clear and red dog flour diets because of inadequate supplies of these fractions. Feed was allowed *ad libitum* in feeders which permitted accurate recording of intakes and water was available continuously during the 14-day feeding period. Temperature in the animal room was thermostatically maintained at 28° C.

RESULTS AND DISCUSSION

Data pertaining to the milling yields and to certain chemical and physical characteristics of the two wheats are presented in Table 2. It is apparent that there were marked differences in milling characteristics,

since the frozen wheat yielded only 14.6 per cent patent flour as against 63.1 per cent for the good wheat and the difference might have been even greater if better milling of the damaged wheat had been possible. Patent flour of the 28 lb./bu. wheat had approximately the same general appearance as red dog flour from the sound wheat. The extensive milling to which the frozen wheat was subjected also may have depleted the shorts and bran of starchy material, thereby accounting for some of the changes in chemical and physical characteristics of these fractions. In most instances the mill fractions from the frozen wheat were higher in protein and swelled more upon wetting than did the corresponding samples from the good wheat.

Statistical analysis of the 2-week mouse gains and of the feed intakes revealed highly significant differences ($P = < .01$) within all the major comparisons except the vitamin treatments. In this instance there was a trend toward improved gains with additional B-vitamins, with a significant difference between the nil and the highest level of supplementation. This effect, however, was discovered to be associated with those diets in which either starch or cellulose was added to modify fibre or bulk and was independent of the quality of wheat or the milling fraction. These findings confirm previous ones (1) to the effect that frost damage does not materially reduce B-vitamins in wheat.

Direct Comparisons of Mill Fractions

Considering first those comparisons having no fibre or bulk modification, it was noted (Table 3) that the mill fractions from 28 lb./bu. wheat were consistently superior to those from sound wheat and particularly so with the two flour samples. The similarity in responses of mice fed patent flour from frozen wheat and those fed clear and red dog flour from control wheat corresponds with the previous observation that these two samples were alike visually. Since neither vitamins nor minerals appeared to be limiting factors in these comparisons, and since the level of protein fed was near the actual requirement level for growing mice, it is possible that the superior performance of the mice fed patent flour from frozen wheat was related to protein quality in the flour. This flour represents a product of high extraction and it has been reported (7) that the outer layers of the wheat kernel contain protein of higher biological value.

An attempt was made to evaluate energy utilization for growth separately from maintenance. Gains and feed intakes were found to be highly correlated ($r = 0.75$, 213 D.F.). Using data on 252 animals, with gains varying from zero to 15 gm., the feed records were converted to approximate digestible calorie intakes by employing digestibility coefficients derived for the various ingredients in an experiment to be reported elsewhere. The regression line indicated 55 Cal. as the 14-day maintenance allowance for a mouse weighing 8.5 gm. Appropriate maintenance allowances were calculated for other weights according to $W^{.72}$ (4) and the maintenance portion, based on the average weight while on test, was deducted from the digestible calorie intake for average mice on each diet to obtain productive calories. On this basis it remained apparent that patent flour from frozen wheat was superior in quality to that from sound wheat and very similar to the lower grades of flour from good wheat.

TABLE 2.—COMPOSITION OF MILL FRACTIONS FROM SOUND AND FROZEN WHEAT SAMPLES

Mill fraction	Percentage yield[1]	Protein %[2]	Cellulose %[3]	Bulk coefficient[4]
		63 lb./bu. wheat		
Patent flour	63.1	16.1	0.2	15
Clear flour	2.9	16.3	3	18
Red dog flour	3.1	16.1	3	15
Shorts	18.6	17.8	5	23
Bran	11.7	16.4	10	34
Whole grain	–	17.3	1.3	17
		28 lb./bu. wheat		
Patent flour	14.6	15.4	3	18
Clear flour	3.5	17.2	4	18
Red dog flour	5.4	17.6	5	23
Shorts	51.0	21.0	6	32
Bran	25.0	18.5	10	38
Whole grain	–	19.6	6.6	35

(1) Recovery of material after milling was 99.4 and 99.5 per cent for the two wheats.
(2) N ×6.25, calculated on a dry matter basis. Analyses for whole grain are on cleaned but unscoured samples.
(3) Values estimated for the mill fractions, analysed for whole grains.
(4) ml. occupied by 10 gm. material in 0.9 per cent saline.

TABLE 3.—GAINS AND FEED UTILIZATION OF MICE FED MILL FRACTIONS FROM SOUND AND FROZEN WHEATS IN RATIONS HAVING VARIOUS FIBRE AND BULK MODIFICATIONS

Milling fraction	Animal responses[1]	Nil		7% Cellulose		Equalized wet bulk	
		63 lb. wheat	28 lb. wheat	63 lb. wheat	28 lb. wheat	63 lb. wheat	28 lb. wheat
Patent flour	Gain, gm.	4.3	10.9	4.3	12.6	1.1	8.2
	Feed, gm.	36	44	35	44	26	45
	Adjusted gain, gm.	4.6	9.9	4.7	11.6	2.9	7.0
	Prod. Cal./gm. gain	11	5	10	4	12	6
	Dig. Cal./gm. feed	3.1	3.1	3.0	3.0	2.7	2.7
Clear+red dog flour	Gain, gm.	10.5	13.2	11.2	11.6	8.8	10.5
	Feed, gm.	45	45	48	45	38	44
	Adjusted gain, gm.	9.4	12.1	9.6	10.4	8.7	9.5
	Prod. Cal./gm. gain	6	4	6	5	3	5
	Dig. Cal./gm. feed	3.1	3.1	3.0	3.0	2.7	2.9
Shorts	Gain, gm.	5.9	7.1	11.5	6.6	3.4	12.3
	Feed, gm.	32	40	43	35	28	47
	Adjusted gain, gm.	6.7	6.7	10.7	7.0	4.9	10.8
	Prod. Cal./gm. gain	4	6	4	6	4	6
	Dig. Cal./gm. feed	2.8	2.9	3.0	3.0	2.7	3.3
Bran	Gain, gm.	0.6	1.7	6.5	6.3	11.5	11.5
	Feed, gm.	22	27	37	34	45	44
	Adjusted gain, gm.	4.1	4.4	6.7	6.8	10.3	9.9
	Prod. Cal./gm. gain	–	4	5	3	6	6
	Dig. Cal./gm. feed	2.3	2.4	2.7	2.6	3.2	3.3

(1) Average responses based on 12 animals, except for clear+red dog flour which involves 6 animals per treatment. Necessary differences for P = .05 and 12 mice were 1.4 gm. for gains; 5.7 gm. for feed and 0.5 gm. for adjusted gains. With 6 mice, the necessary differences were 2.0, 8.1 and 0.7 gm. respectively.

Comparisons of clear and red dog flour from the two wheat samples again showed the frozen wheat fractions to be superior for growth promotion and in efficiency of feed utilization. This is especially interesting since all protein in the 28 lb./bu. wheat diets was derived from flour, whereas the control diets contained 1.24 per cent of vitamin-free casein.

Most of the difference between the shorts fractions from the two wheats appears to be associated with the differences in feed consumption because gains, when adjusted for feed intake differences, were equal. Efficiency of energy utilization was reasonably high in both cases as compared to other rations in the experiment which allowed normal growth (i.e., 12 or 13 gm.) but the mediocre growth rates obtained suggest that digestible calorie intakes were below optimum. It is worth noting, however, that the mice fed shorts from good wheat consumed only 80 per cent as many digestible calories as did those fed patent flour from the same wheat and yet gained significantly more.

Ability to consume sufficient feed appeared to be the limiting factor for mice fed on bran rations. These mice consumed between one-third and one-half as much digestible energy as those fed clear and red dog flour. Energy utilization was satisfactory when enough energy was consumed to permit growth.

These comparisons show that, whereas in earlier work (1) the 28 lb./bu. wheat proved to be inferior to 63 lb./bu. wheat, the major mill fractions of frozen wheat were capable of supporting faster growth when tested separately. There appear to be no special B-vitamin problems and the possible amino acid differences are probably related to the relative proportions of outer layers of the kernel. The frozen wheat was more difficult to mill and produced 76 per cent bran and shorts as opposed to 30.3 per cent in good wheat. It cannot be assumed that corresponding mill fractions from the two wheats were morphologically identical.

Comparisons of Mill Fractions in Diets with Cellulose Content Standardized

Preliminary studies indicated that 7 per cent cellulose was about the optimum level in rations containing 63 lb./bu. wheat as the main ingredient. The addition of cellulose (and also casein) to patent flour fractions only improved that from low quality wheat. Equal percentages of cellulose were added to each flour so the differences do not appear to be due to the additional fibre. Protein quality differences may have been involved but this cannot be ascertained from these data.

No significant effects resulted from adjusting the cellulose content to approximately 7 per cent in the case of clear and red dog flour from 63 lb./bu. wheat, but there was a depression noticed with the sample from 28 lb./bu. wheat and which was largely due to a reduction in digestible calorie intake.

The addition of starch and casein to obtain 7 per cent cellulose in shorts rations improved the sample from good wheat but had no effect on that from 28 lb./bu. wheat.

Adjustment of the bran rations to 7 per cent cellulose involved the addition of about 18 to 20 per cent starch and 3 to 5 per cent casein as partial substitutes for bran. These changes resulted in significant increases in both gains and feed intakes; however, the gains remained well below normal. There were no differences between sources of bran.

It is readily apparent from these results that standardizing cellulose contents in these diets failed to permit animals to perform alike. Nevertheless there are indications that feed density, in some respect, was involved in the performance obtained.

Comparison of Mill Fractions in Diets with 'Wet Bulk' Standardized

Studies of the water-holding capacity and swelling of feeds indicated that behaviour in the presence of liquids did not always correspond with fibre content or dry density. Hence an attempt in this experiment was made to standardize the rations somewhat in accord with their physical characteristics in the stomach. In order to bring the *wet bulk coefficient* of the patent flour rations to the desired range it was necessary to add about 23 per cent cellulose. This resulted in depressed gains compared to unmodified flour diets from both wheats, but the 28 lb./bu. material remained distinctly superior to the sample from sound wheat. Since there was no improvement in utilization of energy, despite a large increase in the amount of casein added and despite an increased protein:digestible energy ratio, it now seems doubtful that protein quality was the main limiting factor in the flour from good wheat.

Equalization of bulkiness of clear+red dog flour gave results similar to those obtained with the patent flours but of smaller magnitude.

Mice fed the shorts rations, with bulk equalized, showed marked differences in gains. It will be recalled that cellulose was added to the shorts from good wheat and that starch and casein were added to the shorts from frozen wheat in order to regulate the density. These modifications resulted in 2.7 as opposed to 3.3 digestible Cal./gm. of feed which probably accounts, at least in part, for the observed differences in gains.

Equalization of wet bulk resulted in equal responses from the two bran samples and in approximately normal gains in the mice. As in the case of shorts these rapid gains were undoubtedly correlated with the increased digestible energy content of the ration.

It is readily apparent from the above results that standardization of either cellulose (fibre) content of the diet or *wet bulk* (as it may prevail for a time in the upper gastro-intestinal tract) effected no consistent improvement in, or explanation of, the feeding value of mill fractions. It is equally obvious that some aspect of physical behaviour of diets in the digestive system was involved. There is evidence that rate of passage varies (2, 5, 6); that absolute capacity of the digestive system may change in response to diets varying in fibre (alfalfa) content (3), and there are differences in the nature of digestive residues which, in turn, may influence laxation, feed consumption and growth rates. The latter possibly may have been involved in the failure of the cellulose content of pure cellulose and that naturally occurring in bran or shorts to produce similar growth responses in the mice. The cellulose was almost indigestible and, therefore, would retain its initial characteristics, whereas the initial characteristics of bran undoubtedly changed as digestion progressed. There is a definite need for more research on the physical aspects of non-ruminant feeds in order to elucidate reasons for differences in responses of animals fed diets that presumably are balanced nutritionally and non-toxic.

Specifically regarding frozen wheat, these tests have revealed no deleterious effects of frost damage on the major mill fractions of wheat weighing 28 lb./bu. after cleaning. In fact, the frozen wheat fractions promoted better growth than their counterparts from good wheat. It is concluded, therefore, that the reduced feeding value of frozen wheat weighing less than about 45 lb./bu. can be attributed mainly to the preponderance of bran and shorts fractions, as opposed to endosperm, which reduces the amount of available energy per unit weight of wheat and in part to certain peculiar and yet unexplained effects of ration density which influence feed capacity of the animal.

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EFFECTS OF LOW FLUCTUATING TEMPERATURES ON FARM ANIMALS

I. INFLUENCE OF AMBIENT AIR TEMPERATURE ON THE RESPIRATION RATE, HEART RATE, AND RECTAL TEMPERATURE OF LACTATING HOLSTEIN-FRIESIAN COWS

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ABSTRACT

This report presents data on the effect of low fluctuating ambient air temperatures on the rectal temperature, heart rate, and respiration rate in lactating Holstein-Friesian cows.

Daily minimum ambient air temperature (DMAAT) inside the uninsulated University of Saskatchewan loose-housing shed ranged from −5° F. to 38° F. As ambient temperature decreased, rectal temperature and heart rate increased, while respiration rate decreased. Levels of significance were 10, 9, and 1 per cent for regressions of rectal temperature, heart rate, and respiration rate, respectively, on DMAAT. Levels of significance were 7, 10, and 1 per cent for regressions of rectal temperature, heart rate, and respiration rate, respectively, on degree hours per day (d-h/day). Degree hours per day is a measurement unit developed by the authors and is based on time and difference in degrees from 50° F.

Change in rectal temperature and heart rate were not significantly ($P = >.05$) correlated with either change in d-h/day or change in DMAAT. Change in respiration rate was significantly ($P = <.02$) and negatively correlated with change in d-h/day and significantly ($P = <.06$) and positively correlated with change in DMAAT.

Heart rate, rectal temperature, and respiration rate were not significantly correlated with each other. However, change in respiration rate was positively correlated with change in rectal temperature ($P = <.03$).

While the influence of low temperatures resulted in small changes in these physiological characteristics compared to those experienced elsewhere in high temperature zones, it cannot be concluded that lactating cows were entirely free of thermal stress at temperatures as low as 0° F.

INTRODUCTION

Economic pressures of various kinds are forcing the production of livestock into climatic environments that are increasingly more remote from the considered ideal for optimal production and feed utilization. Among recent developments aimed at more efficient production is the adoption of loose-housing for dairy cattle, whereby shelter is provided by inexpensive, uninsulated, partially open-sided sheds. In many parts of Canada this type of housing subjects cows to temperatures well below the zone of thermal neutrality.

Most of the data concerning climatic effects on milk production have involved either high temperatures or moderately low constant temperatures. It is essential that these data be supplemented with cold fluctuating temperature effects in the ranges normally experienced throughout much of agricultural Canada.

It is also important to have experimental results which permit the precise definition of temperatures at which surplus heat generated in the maintenance of various body functions may be insufficient to maintain normal body temperatures and, further, to have information on the

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quantitative relationships between energy requirements and temperature maintenance in cold environments. Below these temperatures it becomes necessary for animals to use nutrients specifically for homeothermy. It is, of course, well known that the lower critical temperature varies with species, stage of lactation, body size, physiological age, etc. In addition to temperature responses, the effects of relative humidity on livestock performance is important in relation to dairy cattle management and housing design.

Because studies of environmental physiology involve so many variables and scientific disciplines or, alternatively, such expensive equipment with which to regulate all but one or two variables, such studies were rarely undertaken until relatively recently. Now, however, much is being published on the environmental physiology of farm animals. Comprehensive reviews have appeared under the authorship of Lee and Phillips (15), Findlay and Beakley (6), Hancock (8), Brody (3), and others.

Experimental results reported in this and papers to follow in this series are intended to supplement data reviewed by the authors listed. Eventually accumulated data will permit specific recommendations on breeding, feeding, and management, which will minimize environmental stress on farm animals.

Thermal stress is reflected in easily observable changes in pulse rate, respiration rate, and rectal temperature, although the whole body reacts to thermal stress by an elaborate series of chain reactions (4). The most obvious index of thermal stress is body temperature response. Deviation from normal rectal temperature indicates that the animal is under stress, that its homeothermic mechanisms are overtaxed (4).

Very little has been reported about the effects of low temperatures on the rectal temperatures of lactating cows. Lee and Phillips (15) indicate that cold reduces rectal temperature, unless there is compensatory exercise and other energy transformations. Brody and associates (11, 12, 20) found that decreasing the temperature from the range of 50° to 70° F. down to 5° to 9° F. did not affect rectal temperature in Holstein, Jersey or Brahman cows. In another study temperature variation was insufficient to establish correlations (10).

On studying the effect of ambient temperature on respiration rate in cattle, Kibler and Brody (11, 12) found that low temperatures decreased respiration rate more in Holstein and Jersey than in Brahman cows; that there was no difference in response to temperature between Holstein and Jersey cows, and that minimal rates of 10 to 15 respirations per minute were observed at 4° F. Kelley and Rupel (10), using lactating Guernsey and Holstein-Friesian cows, observed that large changes in minimal temperature (10° to 15° F.) were accompanied by large changes in respiration rate. They recorded respiration rates per minute of 30.4 at 65° F.; of 27.3 to 29.4 at 60° F.; of 19.9 to 22.6 at 55° F.; and of 19.5 to 20.3 at 50° F. Lee lists depressed respiration as one of the effects of low temperature (14).

Brody and associates (12, 20) observed slight increases (approximately 8 per cent) in pulse rate when Holstein, Brahman, and Jersey cows were subjected to chamber temperatures below 40° F. Others (10) found that pulse rate responses to activities such as eating, drinking, standing, rising, etc., masked possible temperature effects.

MATERIALS AND METHODS

Data used in these studies were from dairy cattle maintained at the University of Saskatchewan during the winter of 1956-57. All animals were registered Holstein-Friesian cows or heifers and were maintained in a loose-housing unit. The unit comprised a 78 × 52-foot uninsulated pole barn, covered with aluminum sheeting, a heated milking parlour, and an exercise yard which was accessible from the barn through a 10′6″ × 8′6″ door which was never closed. The loose-housing shed had an over-all area of approximtely 4,050 sq. ft., of which 700 sq. ft. was a feeding area kept free of manure and bedding. The manure pack accumulated on an area of approximately 2400 sq. ft., and feed storage facilities occupied the remaining 950 sq. ft. Capacity of the shed was approximately 50,000 cu. ft. when empty and decreased by about 10,000 cu. ft. during the manure-pack build-up. Long wheat straw bedding was distributed over the manure pack daily in amounts necessary to keep the cows clean. The University herd, comprising cows and heifers in various stages of lactation, occupied the loose-housing shed throughout the winter.

All animals had free access to average quality hay and concentrates were fed twice daily according to U.S. National Research Council recommendations for dairy cattle (16). Composition by weight of the concentrate mixture was: wheat, 20 per cent; oats, 27 per cent; barley, 40 per cent; linseed meal, 10 per cent; and mineral mixture, including salt, 3 per cent. Water was available to the herd at all times in a heated water-bowl.

Temperatures were automatically recorded both outside and inside the barn by an electronic recorder. Inside the barn thermocouples were set in the manure pack at depths of 6 to 12 inches below the surface and at heights above the pack of 1.5 and 4.5 feet. Relative humidity was recorded at 4.5 feet above the manure pack, using an hair hygrometer.

Portable stanchions were placed on the manure pack for 15-day test periods in January, February, and March. An interim period of approximately 14 days separated each test period. Six mature cows in the declining phase of lactation were confined in the stanchions to permit accurate measurements of roughage and water intakes. Each animal was weighed on entering and leaving the portable stanchions. The same six cows were confined in each of the three 15-day test periods.

All lactating animals occupying the loose-housing unit were milked twice daily. Milk from the six experimental cows, both when free and during confinement, was analysed. Factors studied and details of analyses will be reported in a later publication.

Heart rates and respiration rates were determined, using a standard clinical stethoscope, placed on the lower fore-rib of the standing animal. Time was taken on the sweep second-hand of a wrist-watch. Continuous readings were made until two consecutive readings agreed. Time intervals selected for heart rate and respiration rate recordings were one-quarter and one minute respectively. Rectal temperatures were recorded daily on standing animals, using a standard clinical veterinary thermometer. All readings were taken at approximately 11.00 a.m. daily on each of the six experimental animals on each day of confinement during the three test periods.

TABLE 1.—Average rectal temperatures, heart rate per minute, and respiration rate per minute of lactating cows for various levels of total degree-hours per day

d-h/day level	Average daily temperature (°F.)	Rectal temperature (°F.)		Heart rate per minute		Respiration rate per minute		d.f.
		Mean	s.d. ±	Mean	s.d. ±	Mean	s.d. ±	
1152	2.0	101.02	.60	70.7	6.02	14.3	2.16	5
1142	2.4	101.23	.68	70.9	7.10	17.6	2.94	11
1132	2.8	101.50	.42	70.7	6.53	17.0	3.03	5
1102	4.1	101.14	.63	67.2	6.80	15.9	1.93	11
1052	6.2	101.45	.48	63.7	4.47	14.7	2.24	5
1042	6.6	100.80	.52	72.3	4.45	20.0	2.53	5
1002	8.2	101.25	.33	71.0	6.42	16.7	2.72	5
992	8.7	101.37	.52	70.7	5.35	17.6	2.54	11
982	9.1	101.50	.34	70.7	6.53	17.0	2.53	5
972	9.5	101.15	.58	69.0	5.62	18.5	2.32	5
902	12.5	99.98	.74	66.3	5.12	17.0	1.26	5
882	13.2	101.11	.22	70.7	6.84	19.7	5.53	11
852	14.5	101.22	.54	70.7	6.11	16.0	3.77	11
832	15.3	101.00	.37	68.0	7.48	16.7	2.24	5
822	15.7	101.40	.43	69.7	5.71	16.0	2.37	5
782	17.4	100.97	.51	76.0	2.53	18.5	3.44	5
641	23.3	101.35	1.18	70.1	9.34	18.4	3.87	17
631	23.7	101.33	.28	66.0	2.53	30.2	4.27	5
591	25.4	101.28	.48	66.0	4.90	17.3	2.49	5
551	27.0	101.38	.50	70.3	7.33	20.7	4.96	11
541	27.5	101.10	.55	70.1	8.92	22.9	5.49	11
531	27.9	101.57	.53	73.4	5.46	19.7	3.19	5
501	29.1	100.67	.53	67.8	5.01	19.3	3.53	11
471	30.4	101.17	.17	70.0	7.48	25.3	4.58	5
451	31.2	100.93	.45	63.4	3.26	19.2	3.07	5
411	32.9	101.58	.53	65.7	5.71	19.7	2.32	5
371	34.5	100.52	.57	65.1	7.54	19.6	2.78	11
290	37.9	100.58	.35	66.7	3.26	21.3	2.72	5
250	39.6	100.80	.38	69.0	5.94	28.0	2.86	11
230	40.4	100.62	.23	67.0	3.03	25.0	2.37	5
170	42.9	100.87	.49	68.5	4.83	28.8	5.64	11
110	45.4	100.32	.29	66.4	3.19	20.7	3.19	5

TABLE 2.—Average rectal temperatures, heart rate per minute, and respiration rate per minute of lactating cows for various daily minimum ambient air temperature levels

Minimum temperature (°F.)	Rectal temperature (°F.)		Heart rate per minute		Respiration rate per minute		d.f.
	Mean	s.d. ±	Mean	s.d. ±	Mean	s.d. ±	
0	101.62	.30	62.7	2.05	14.7	0.82	5
2	101.30	.62	68.5	7.13	16.6	3.01	17
3	101.03	.62	69.3	5.31	15.3	1.61	5
4	101.50	.41	70.7	6.53	17.0	3.03	5
5	100.54	.54	72.1	5.62	16.9	2.07	11
6	101.04	.48	69.5	5.56	17.1	3.11	17
7	101.37	.34	70.8	6.18	16.8	2.52	11
10	101.05	.48	73.1	6.06	20.1	5.65	11
11	101.10	.55	71.1	4.94	18.0	3.13	11
12	101.37	.35	69.0	5.94	23.4	8.39	11
14	100.69	.56	68.4	6.49	17.1	1.94	17
20	101.47	.98	70.5	8.83	18.8	6.11	23
21	101.50	.79	71.0	8.17	25.0	6.75	5
22	101.50	.69	66.7	6.03	17.8	3.66	5
24	100.88	.57	68.2	5.98	18.9	1.85	17
26	100.92	.73	69.3	5.49	19.5	3.25	17
27	101.17	.17	70.0	7.48	25.3	4.58	5
28	100.92	.45	63.3	3.26	19.2	3.07	5
29	101.58	.53	65.7	5.71	19.7	2.32	5
32	100.88	.52	64.3	4.18	20.8	2.24	5
34	100.58	.35	66.7	3.29	21.3	2.72	5
35	100.62	.23	67.0	3.03	25.0	2.37	5
36	100.80	.38	69.0	5.94	28.0	2.86	11
37	101.07	.37	68.0	3.58	30.7	6.62	5
38	101.00	.54	67.6	4.89	32.8	4.45	11

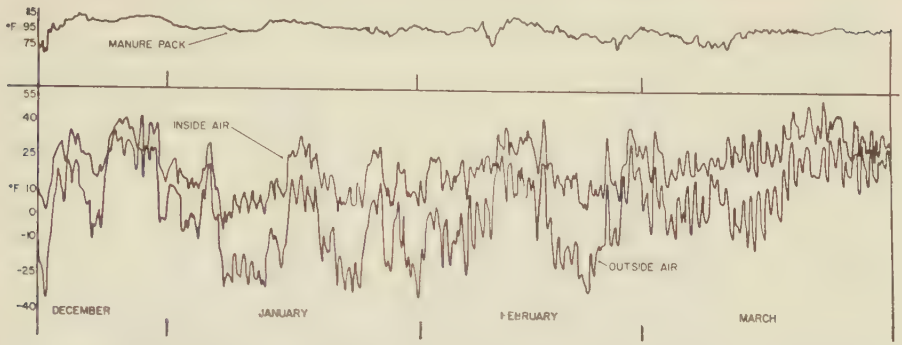

FIGURE 1. Inside and outside ambient air temperatures and manure pack temperatures during the experimental period.

RESULTS AND DISCUSSION

Average manure-pack as well as inside and outside ambient temperatures were recorded at 24-minute intervals and appear in Figure 1. With the exception of periods following manure-pack thermocouple relocation, manure-pack temperatures ranged from 82° to 116° F. Factors modifying inside ambient temperatures were particularly apparent during periods when outside ambient temperatures fell below 0° F. The significance of this will be discussed in a later publication. Since relative humidity at cow height (4.5 feet) was constantly in excess of 90 per cent, except during periods of rapid temperature rise, it was not possible to evaluate the effect of humidity on the factors studied. For that reason relative humidity was not included in Figure 1. One overriding environmental condition was high relative humidity and results, therefore, must be interpreted with due cognizance of this fact.

During the total experimental period, extending from December 15, 1956, to March 31, 1957, minimum outside ambient temperature ranged from −22° to 38° F. Minimum, maximum, and mean inside ambient temperature ranged from −5° to 38° F., from 3° to 52° F., and from 0° to 46° F., respectively.

Degree-hours per day were calculated from inside ambient temperatures. A degree-hour (d-h) is a unit developed here and is based upon temperature difference and time. It is a variation of meteorological degree-days (17) and employs 50° F. as an environmentally ideal basal value for dairy cattle (2, 10, 11, 20). For any one hour, when the mean temperature is less than 50° F., there are as many degree-hours as there are Fahrenheit degrees difference in temperature between the mean temperature for the hour and 50° F., i.e., the colder the temperature, the larger the d-h value. An average daily temperature may be obtained simply by dividing total degree-hours per day by 24 and subtracting the result from 50° F. Total daily degree-hours ranged from 110 to 1202 degree-hours during the experimental period (Figure 2).

Rectal Temperatures

Analyses of data (Tables 1, 2, and 3) indicated that rectal temperatures of lactating Holstein-Friesian cows in the declining phase of lactation

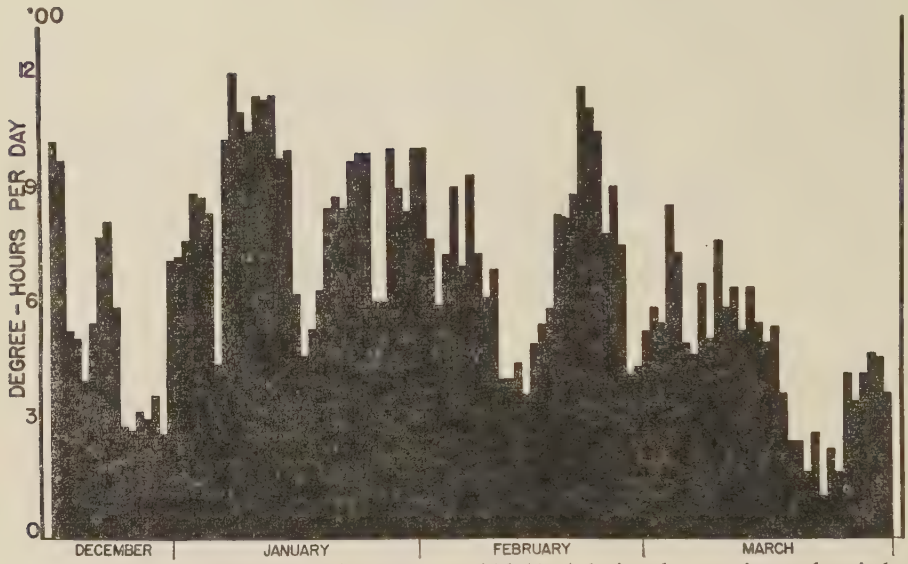

FIGURE 2. Histogram of degree-hours per day (d-h/day) during the experimental period.

increased as temperatures decreased. Upon regressing average rectal temperature of the six experimental cows on total degree-hours per day (d-h/day) and daily minimum inside air temperature (DMAAT), the levels of significance were found to be 7 per cent and 10 per cent, respectively. Workers in Missouri (11, 12) reported that rectal temperatures in Holstein, Jersey and Brahman cattle were constant at chamber temperatures ranging from 70° to 5° F. Kelly and Rupel (10) and Kriss (13) found that environmental temperature effects on rectal temperature were masked by other environmental stimuli such as eating, drinking, digestion, season, time of day and exercise. Had more severe limitations of variation in feed and water intake been imposed on our animals, the resulting reduction in variation within animals undoubtedly would have resulted in higher level of statistical significance or rectal temperature differences at various low temperatures. The importance of controlling other environmental influences when measuring the influence of low temperature on rectal temperature is evident in Figure 3. Rectal temperature differences of only 1 degree Fahrenheit remain within one standard deviation of the mean. A similar situation existed in beef cattle (19).

The mean rectal temperatures of 101.06° F. approximated those observed in dairy cattle by Gaalaas (7), Kriss (13), and Hewitt (9) but several individual observations fell below the range cited by Dukes (5).

The rise in rectal temperature recorded when ambient temperatures declined is an interesting example of physiological adjustment to environmental change. At cold temperatures gradients of temperatures within animals are large, the lowest temperatures being at the exterior (13, 18). By increasing the temperature of deep tissues, the animal is able to maintain homeothermy in vital organs which would otherwise be upset by the return of chilled blood from the periphery. Body heat losses, particularly by conduction and convection, are also reduced to a minimum.

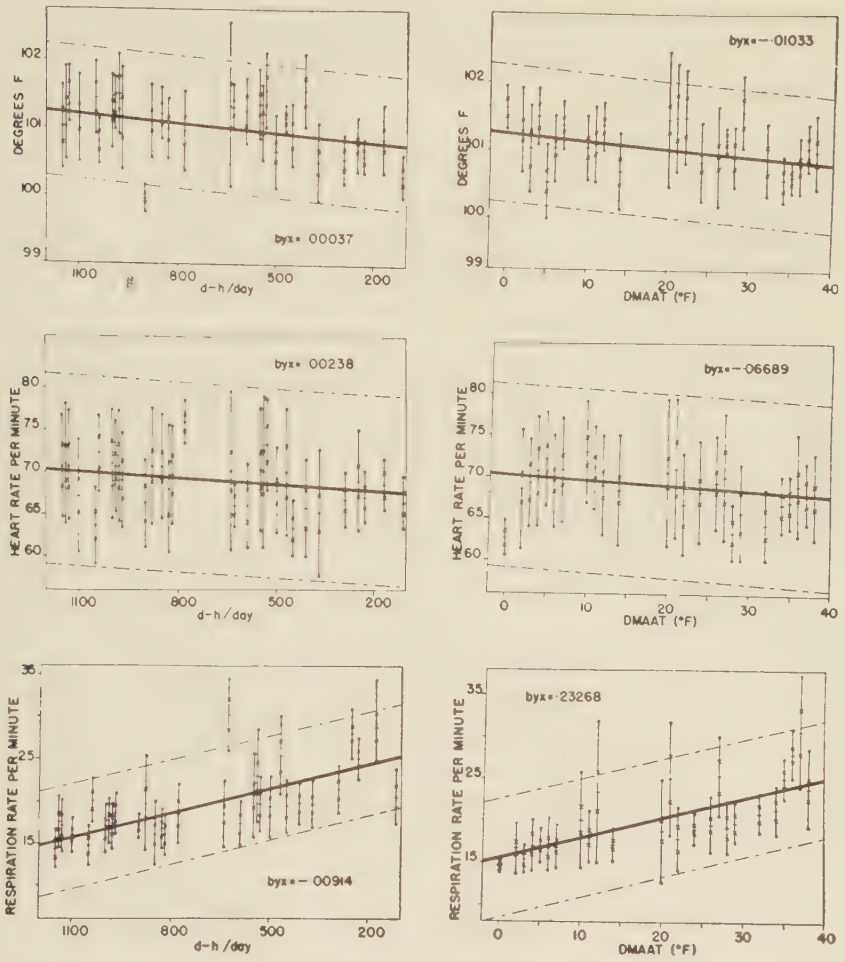

FIGURE 3. Effect of temperature on physiological activities:
Upper left: d-h/day on rectal temperature
Upper right: DMAAT on rectal temperature
Middle left: d-h/day on heart rate per minute
Middle right: DMAAT on heart rate per minute
Lower left: d-h/day on respiration rate per minute
Lower right: DMAAT on respiration rate per minute

Legend: ● = standard deviation, x = standard error, — = mean, — — — — — — = standard deviation x 2.

Cold temperature studies, where animals were maintained at constant temperatures in psychrometric chambers, have been criticized because experimental animals were not subjected to temperature fluctuations normally experienced during wintering. Table 4 indicates that, upon regressing average change in rectal temperature from one day to the subsequent day on change in d-h/day and change in DMAAT, the results were not significant. The average change in rectal temperature was .105° F., while average change in d-h/day and DMAAT was 98 degree-hours and 3.6° F., respectively. It must be concluded that low temperature fluctua-

TABLE 3.—Regression of average rectal temperature (Y_1) heart rate per minute (Y_2) and respiration rate per minute (Y_3) on total degree-hours per day (X_1) and minimum inside ambient temperature (X_2)

Regression of	d.f.	r	byx	Significance level
				%
1. Average rectal temperature (Y_1) on total degree hours per day (X_1)	43	.272	.00036	7
2. Average rectal temperature (Y_1) on minimum inside ambient temperature (X_2)	43	−.247	−.01033	10
3. Average heart rate (Y_2) on total degree hours per day (X_1)	43	.248	.00238	10
4. Average heart rate (Y_2) on minimum inside ambient temperature (X_2)	43	−.260	−.06689	9
5. Average respiration rate per minute (Y_3) on total degree hours per day (X_1)	43	−.752	−.00914	1
6. Average respiration rate per minute (Y_3) on minimum inside ambient temperature (X_2)	43	.667	.23268	1

TABLE 4.—Regression of average change in rectal temperature (Y_1), heart rate per minute (Y_2), and respiration rate per minute (Y_3), on change in total degree-hours per day (X_1) and change in minimum inside ambient air temperature (X_2)

Regression of	d.f.	r	byx	Significance level
				%
1. Average change in rectal temperature (Y_1) on change in total degree-hours per day (X_1)	40	−.192	−.00066	N.S.
2. Average change in rectal temperature (Y_1) on change in minimum inside ambient air temperature (X_2)	40	.150	.01408	N.S.
3. Average change in heart rate (Y_2) on change in total degree hours per day (X_1)	40	−.102	.00262	N.S.
4. Average change in heart rate (Y_2) on change in minimum inside ambient air temperature (X_1)	40	.088	.06148	N.S.
5. Average change in respiration rate per minute (Y_3) on change in total degree-hours per day (X_1)	40	−.381	−.01056	2
6. Average change in respiration rate per minute (Y_3) on change in minimum inside ambient air temperature (X_2)	40	.295	.22200	6

tions *per se* do not affect rectal temperature changes in mature lactating Holstein-Friesian cows that have been acclimatized to low temperatures and high relative humidity.

Heart Rate

Physiological factors known to influence heart rate include excitement, muscular exercise, high environmental temperature, altitude, age, sex, size, digestion, sleep, and various pathological conditions within each domestic species. Data gathered during the three confinement periods of this study were analysed to determine the effect of low temperatures on heart rate per minute. Results appear in Tables 1, 2, and 3 and in Figure 3. It may be seen that as DMAAT decreased and d-h/day increased heart rate per minute increased. Regressions of average heart rate per minute on d-h/day and DMAAT were significant at 10 and 9 per cent, respectively. Heart rate per minute increased 2.62 beats per minute as d-h/day increased from 0 to 1200 and 2.68 beats per minute as DMAAT decreased from 40 to 0° F. The percentage increase in heart rate in the range cited for d-h/day and DMAAT was 3.9 and 4.0 per cent, respectively. This is a much less dramatic increase in average heart rate per minute than the increase in pulse rate per minute recorded by Kibler and Brody (11, 12).

Average heart rate per minute recorded during this experiment was 69; the range for all observations was 60 to 96 beats per miute. As indicated in Figure 3, many observations exceeded the normal range of 60 to 70 beats per minute for dairy cattle listed by Dukes (5). The average heart rate observed approximated that reported for dairy cattle by others (1).

Upon regressing average change in heart rate per minute on average change in total d-h/day and change in DMAAT the results were not significant. The average change in heart rate recorded was .05 beats per minute while average change in total d-h/day and DMAAT, as previously reported, was 98 d-h and 3.6° F., respectively. Again, it must be concluded that low temperature fluctuations *per se* do not affect heart rate changes in lactating, mature Holstein-Friesian cows that have been acclimatized to low temperatures and high humidity.

Heart rate is subject to many influences; hence it must be realized that deductions as to cardiac output cannot easily be drawn from the heart rate. While in general an increased heart rate goes with an increased cardiac output, it is not always so. It is, therefore, unwise to attempt an hypothesis regarding the effect of low temperature on any aspect of the cardio-vascular complex other than heart-rate until direct measurements under desirable experimental conditions are available for analysis.

Respiration Rate

Several workers (10, 11, 12, 15, 20) have indicated that respiration rate decreased in dairy cattle as ambient temperature decreased. On the other hand, Findlay and Beakley (6) state, without reference to experimental work, that temperatures down to 0° F. have little or no effect on the respiration rate of cattle. Dukes (5) indicated the normal respiratory rate per minute of mature dairy cattle at rest is 18 to 28.

Respiration rate data gathered during the three confinement periods of this study are summarized in Tables 1, 2, and 3 and in Figure 3. It may be seen that the range in respiratory rate per minute of 10 to 43 considerably exceeded that reported by Dukes. Under the experimental conditions previously described, average respiration rate per minute was 19.8. Upon regressing respiration rate on total d-h/day and DMAAT, it was found that as temperature decreased respiration rate decreased (Table 3). Regressions of average respiration rate per minute on d-h/day and DMAAT were significant at the 1 per cent level. Applying the regression coefficients obtained (Table 3), the change in average respiration rate per minute with cold temperatures may be seen in Figure 3. As total d-h/day increased from 100 to 1200, respiration rate per minute decreased from 25.2 to 15.2. As DMAAT decreased from 40° F. to 0° F. respiration rate per minute decreased from 25.0 to 15.7. The respiration rate per minute decrease closely approximates that reported for Holsteins in a similar temperature range by Kibler and Brody (12).

Results from regressing average change in respiration rate on change in total d-h/day and change in DMAAT were significant at the 2 per cent and 6 per cent levels, respectively. An extreme form of this relationship may be seen at 631 d-h/day in Figure 3. Prior to recording respiration rate inside ambient temperatures had risen approximately 25 degrees in 2 hours. Respiration rates exceeded twice the standard deviation from the regression in all but one of the animals observed. Under those conditions respirations were rapid and shallow; they were in direct contrast to observations made on days where temperature changes were neither as rapid nor as extensive. Without spirometer records, it is impossible to assess the change in minute volume of respired air with temperature changes.

Interrelationships between Rectal Temperature, Heart Rate, and Respiration Rate

In none of the three analyses (Table 5) was there a significant correlation between any two of the three factors studied. We must conclude that low temperatures influence these values through different intermediary agencies, or that the techniques employed for measurement did not permit

TABLE 5.—Interrelationships between rectal temperature, heart rate, and respiration rate

Correlation of	d.f.	r	Level of significance
			%
1. Heart rate with respiration rate	43	−.058	N.S.
2. Heart rate with rectal temperature	43	.236	N.S.
3. Respiration rate with rectal temperature	43	−.118	N.S.
Change in			
4. Heart rate with daily change in respiration rate	40	.096	N.S.
5. Heart rate with daily change in rectal temperature	40	.192	N.S.
6. Respiration rate with daily change in rectal temperature	40	.338	3

the exclusion of other unmeasured environmental influences sufficiently well to permit the establishment of a correlation of statistical significance. Only through study under more carefully controlled or more exactingly measured conditions may the two possibilities be separated.

Correlation coefficients were calculated for change in heart rate, respiration rate, and rectal temperature, each with the other two factors (Table 5). The correlation of change of respiration rate with change in rectal temperature was significant at the 3 per cent level. This was unexpected since respiration rate decreased as temperature decreased while rectal temperature increased under similar circumstances. Further study under more carefully controlled environmental conditions is necessary to resolve this apparent discrepancy in results.

It may be argued that, because changes in absolute values for rectal temperature heart rate, and even respiration rates, were relatively small in the low temperature range studied here and elsewhere (10, 11, 12, 20), lactating cattle are quite comfortable at near 0° F. As further proof these workers cited compensatory mechanisms which enhance cold tolerance. These include removing water from the circulatory system, peripheral vasoconstriction, decreasing the surface area by huddling, decreasing respiration rate, erecting and increasing the amount of protective hair, developing extensive insulating layers of subcutaneous adipose tissue, and increasing appetite and metabolism through endocrinological stimulation and exercise. Collectively all these adjustments are termed acclimatization and, provided the conditioning period is gradual, no sudden changes in animal behaviour and function are noticed. However, it is hazardous to conclude that, because deviations from homeothermy are small, thermal stress at low temperatures must also be small. It may be argued conversely that, in spite of all the physiological adjustments made by the animals, they were unable to maintain complete homeothermy at low temperatures. Obviously the problem is not simple and the solution must represent results from studying interrelationships where the many necessary observations were made simultaneously.

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EFFECTS OF LOW FLUCTUATING TEMPERATURES ON FARM ANIMALS

II. INFLUENCE OF AMBIENT AIR TEMPERATURE ON WATER INTAKE OF LACTATING HOLSTEIN-FRIESIAN COWS[1]

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[illegible]

ABSTRACT

[illegible] changes appeared to be dissipated within 24 hours or overshadowed by the more immediate effects of the environment the following day.

INTRODUCTION

Literature on the water economy of farm animals has been reviewed by Leitch and Thompson (7), Sykes (18), Winchester and Morris (20), and others (13, 14, 15, 16, 19). Relatively little information is available, however, on the effects of below-freezing ambient air temperatures on water metabolism of farm animals. Nevertheless, water utilization is a matter of major practical importance in relation to the productivity of animals housed in cold environments.

This report contains information on the effects of low fluctuation temperatures on water consumption of mature lactating Holstein-Friesian cows.

MATERIALS AND METHODS

The data used in this study were from Holstein-Friesian dairy cows of the University of Saskatchewan herd. [illegible] were maintained under the

[1] [illegible]

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TABLE 1.—AVERAGE WATER INTAKE AND WATER:NUTRIENT INTAKE RATIOS AT VARIOUS LEVELS OF DEGREE HOURS PER DAY

d-h/day	Daily mean temperature	Daily		During subsequent day		Ratio of daily total water intake to[1]				
		Free water consumption	Total water intake	Free water consumption	Total water intake	Daily D.M. intake	D.M. intake during subsequent day	Hay D.M. intake	Total caloric intake[2]	Milk yield
	F.	lb.	lb.	lb.	lb.					
1152	2.0	215	220	190	195	4.49	4.07	7.76	0.96	5.14
1142	2.4	184	189	206	211	3.89	4.51	6.50	1.13	4.69
1132	2.8	169	213	183	188	4.27	3.91	7.22	1.01	5.05
1102	4.1	190	195	187	191	4.07	4.17	6.88	1.09	4.61
1052	6.2	190	194	184	190	4.34	3.86	8.19	1.00	5.07
1042	6.6	183	188	212	207	3.99	4.63	7.09	1.09	4.48
1002	8.2	200	204	171	175	4.76	3.94	9.52	0.91	4.73
992	8.7	198	203	...	...	4.40	....	8.05	0.98	4.81
982	9.1	203	208	200	204	4.75	4.76	9.31	0.91	5.01
972	9.5	194	198	198	203	4.32	4.40	7.98	1.00	4.46
882	13.2	193	198	196	201	4.06	4.14	6.74	1.09	4.57
852	14.5	186	191	193	198	4.07	4.22	7.34	1.07	4.65
832	15.3	192	196	240	204	4.15	5.09	7.38	1.04	4.77
822	15.7	235	244	194	199	5.09	4.00	8.96	0.85	3.24
782	17.4	202	207	...	...	4.63	....	9.22	0.94	5.11
641	23.3	184	189	189	194	4.47	4.28	8.33	0.99	5.01
631	23.7	171	175	193	197	3.94	4.36	7.50	1.10	3.95
591	25.4	154	158	190	194	3.93	4.65	8.40	1.10	3.92
551	27.0	195	199	161	165	4.67	3.89	9.16	0.93	5.07
541	27.5	191	179	187	192	4.32	4.14	7.86	1.00	4.95
531	27.9	186	191	183	188	4.29	4.27	7.66	1.00	5.19
501	29.1	182	187	190	194	4.00	4.68	6.98	1.08	4.69
471	30.4	193	197	206	211	4.36	4.43	8.18	0.99	4.59
451	31.2	192	204	177	182	4.86	4.14	10.49	0.89	4.86
411	32.9	175	179	184	188	4.23	4.61	9.07	0.99	4.72
371	34.5	184	189	183	187	4.22	4.12	7.71	1.02	4.78
290	37.9	152	156	198	202	3.64	4.62	6.67	1.18	4.02
250	39.6	177	182	190	194	4.27	4.53	8.01	1.01	4.85
230	40.4	175	179	...	...	4.12	....	7.51	1.04	5.00
170	42.9	192	196	152	156	4.61	3.64	8.65	0.93	5.19
110	45.4	198	202	175	179	4.62	4.12	8.35	0.93	5.66
Averages— 679.3	21.7	189.1	193.3	189.1	193.3	4.30:1	4.30:1	7.94:1	1.01:1	4.76:1

[1] In each ratio daily total water intake in pounds is represented in the table and the nutrients and milk in pounds were reduced to unity.
[2] Ratio is grams of water:total caloric intake per day.

(Average water intake and water:nutrient intake ratios at various levels of daily minimum ambient air temperatures approximate the values appearing in Table 1 and may be obtained on request from the senior author).

experimental conditions reported previously (8). Six cows were confined in portable stanchions on the manure pack for 14-day periods in January February, and March, 1957. An interim period of approximately 14 days separated each test period. All animals were weighed at the commencement and termination of each test period. Hay was provided *ad libitum* to each cow and amounts were recorded daily. Cool water was offered to each animal five times daily at regular intervals and the intake was measured in pounds. Concentrates were fed approximately according to the "*Nutrient requirements for dairy cattle*" (12).

Caloric contents of feeds and feces were determined with a Parr oxygen-bomb calorimeter (3). Water content of feedstuffs was determined by drying aliquots to constant weight (2). Levels of statistical significance were determined using values presented by Fisher and Yates (4).

RESULTS AND DISCUSSION

The effects of total degree-hours per day (d-h/day) and daily minimum ambient air temperature (DMAAT) (8) were determined on the following factors: 1) free water consumption; 2) total water intake; 3) free water consumption during the subsequent day; 4) total water intake during the subsequent day; 5) total water: total dry matter intake ratio; 6) total water: total dry matter intake ratio during the subsequent day; 7) total water: hay dry matter intake ratio; 8) total water: total caloric intake ratio, and 9) total water: milk yield ratio. Results and discussion of each of these analyses are presented in the order listed. Each analysis represents 41 daily records on each of 6 experimental cows or a total of 246 individual observations. The individual values recorded for each factor for each temperature category in Table 1 are averages of 6 to 24 observations.

1. *Effect of d-h/day and DMAAT on Average Daily Free Water Consumption*

Contrary to the popular belief that livestock refuse to drink large quantities of water at lower temperatures, free water consumption increased as temperatures decreased. As d-h/day increased and DMAAT decreased, the increase in average daily free water consumption was significant at the 2 per cent level (Table 2). Even at temperatures below 10° F., individuals consumed over 100 lb. of water during a single drinking interval of less than 10 minutes, although the average consumption per drink fell much below this value. Free water consumption varied considerably within individuals from day to day and between individuals, depending on stage of lactation, body size and feed intake. This is reflected in Figure 1 in which the mean, the standard error of the mean, and the standard deviation of intake recorded at each temperature gradient have been illustrated. Daily free water consumption averaged approximately 189 lb. per cow per day and was well within the range of water: milk yield ratios given by Morrison (11).

Missouri workers (14) reported a slight increase in water consumption with declining temperatures and associated it with increased hay intake. They also noted a slight increase in drinking frequency.

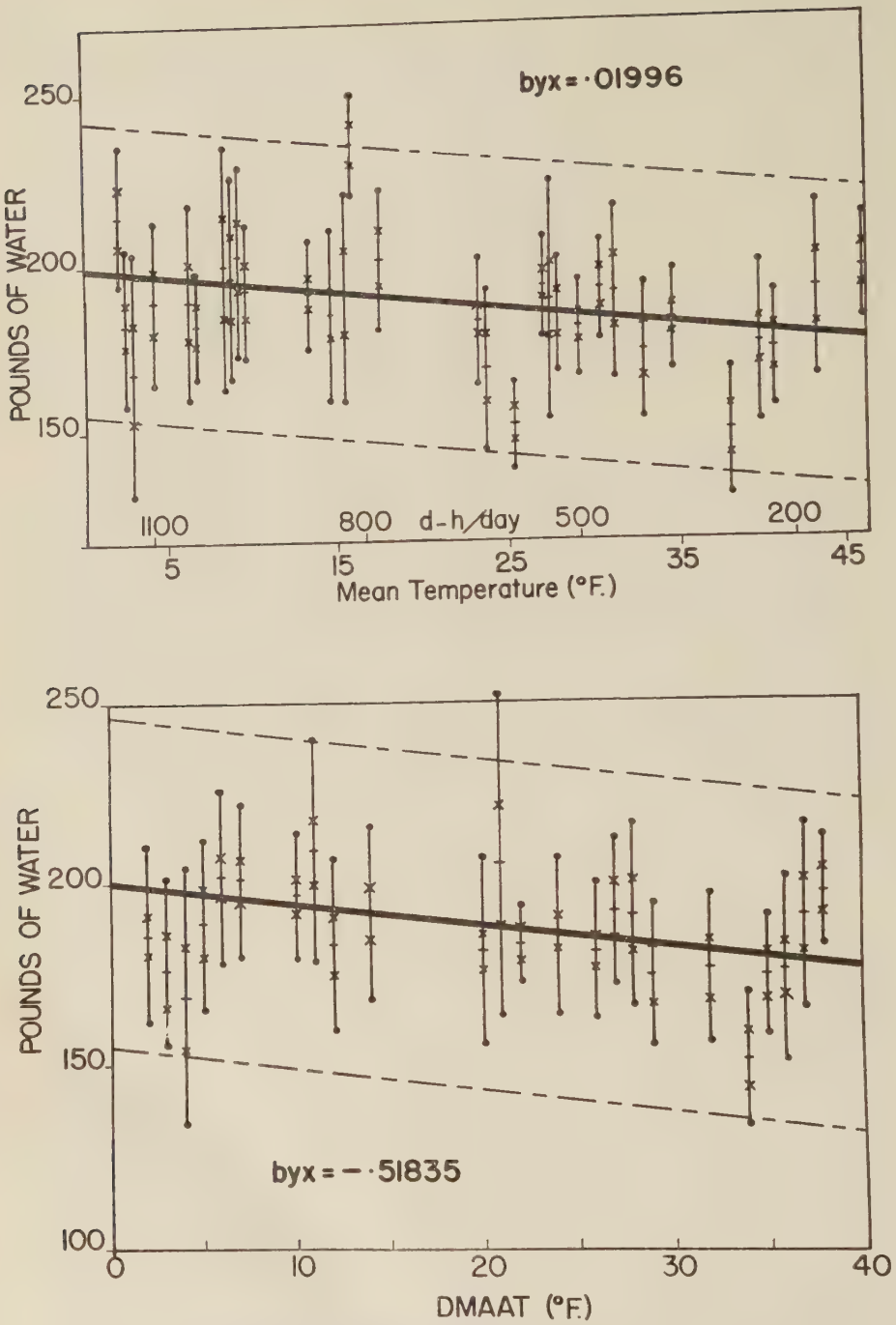

FIGURE 1.—Relationship between temperature represented by d-h/day and DMAAT (X) and pounds of free water consumed daily per cow (Y).
Legend: ● standard deviation, x standard error, — mean, —— – —— – standard deviation x 2.

2. *Effect of d-h/day and DMAAT on Average Daily Total Water Intake*

Sykes indicated (18) that the ingestion of free water should be termed *water consumption* while the ingestion of free water plus the water in feedstuffs, i.e. total water ingested, should be termed *water intake.* Sykes' terminology has been used in this paper. As indicated in Table 1, free water consumption comprised almost 98 per cent of the average daily total water intake of the experimental cows. It could be expected, therefore, that results obtained from regressing average daily free water consumption on d-h/day and DMAAT apply equally as well as a similar regression involving average total water intake. Such was the case. The regression of total water intake on d-h/day and DMAAT was statistically significant at the 2 per cent level (Table 2).

3. *Effect of d-h day and DMAAT on Average Daily Free Water Consumption during the Subsequent Day*

It is well known that under cold conditions the appetite is stimulated and that water intake tends to parallel energy intake (6, 7, 13, 14). The exact mechanism for this has not been established fully, but adrenalin and thyroxine are known to increase hunger contractions under certain conditions.

On regressing average free water consumption during the subsequent day on d-h/day the result was significant at the 3 per cent level. The carry-over effect of d-h/day was not significant for longer periods. Upon regressing average free water consumption during the subsequent day on DMAAT, however, the result was significant only at the 9 per cent level. Similarly, the carry-over effect of DMAAT was not significant for longer periods. Thus, it may be seen that mean temperature had a more pronounced effect than minimum temperature on free water consumption during the subsequent day, and that temperature effects occurred both coincident with and following temperature changes.

4. *Effect of d-h/day and DMAAT on Average Daily Total Water Intake during the Subsequent Day*

The regression of average total water intakes during the subsequent day (Table 2) on d-h/day was significant at the 3 per cent level. The regression of water intake during the subsequent day (Table 2) on DMAAT was significant only at the 8 per cent level. As with free water consumption, the carry-over effects of temperature on average total water intake were not significant for longer periods.

It would appear that such thermal stress effects as the cows experienced in response to temperature changes were mostly dissipated within 24 hours, or were overshadowed by the immediate effects of the environment the following day.

5. *Effect of d-h/day and DMAAT on the Ratio in Pounds of Daily Total Water Intake:Dry Matter Intake*

Larsen, Hungerford, and Bailey (5) using dairy cattle, found that the ratio of water to dry matter intake was 30 per cent higher at 25° C.

TABLE 2.—REGRESSIONS OF AVERAGE WATER CONSUMPTION, WATER INTAKE, AND WATER:NUTRIENT RATIOS (Yx) ON TOTAL DEGREE-HOURS PER DAY AND DAILY MINIMUM AMBIENT AIR TEMPERATURE (x)

Analysis No.	Factor	Regressions of factors on d-h/day				Regressions of factors on DMAAT			
		df	r	byx	Significance level	df	r	byx	Significance level
1	Free water consumption	39	.367	.01996	2%	39	−.365	−.51835	2%
2	Total water intake	39	.392	.02109	2%	39	−.373	−.52364	2%
3	Free water consumption during the subsequent day	39	.343	.01825	3%	39	−.274	−.39063	9%
4	Total water intake during the subsequent day	39	.345	.01817	3%	39	−.281	−.39721	8%
5	Total water:dry matter intake ratio	39	−.081		N.S.	39	.089		N.S.
6	Total water:dry matter intake ratio during the subsequent day	39	−.053		N.S.	39	.107		N.S.
7	Total water:hay dry matter intake ratio	39	−.208		N.S.	39	.190		N.S.
8	Total water:total caloric intake ratio	39	−.130		N.S.	39	.13		N.S.
9	Total water:milk yield	39	−.155		N.S.	39	.195		N.S.

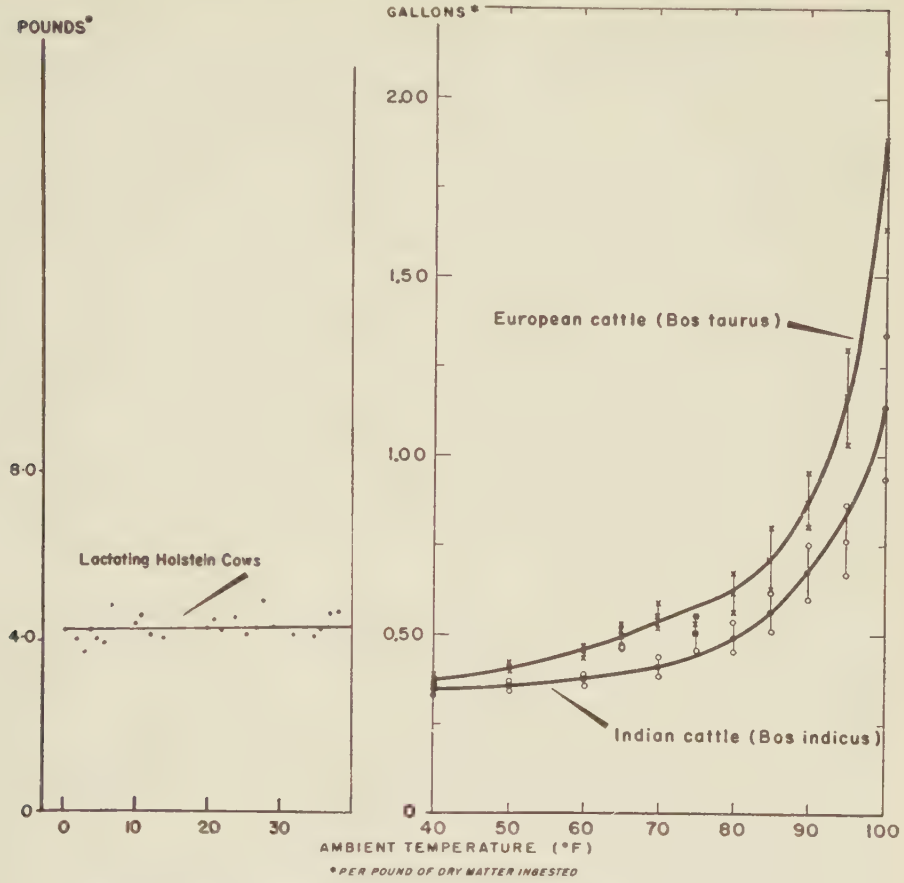

FIGURE 2.—Water intake in pounds and gallons (ordinate) expressed as a function of dry matter consumption and ambient temperature (abscissa). The 40° to 100° F. temperature range shown is from Winchester and Morris (20).

than at average temperatures near 0° C. Ritzman and Benedict (17) found water intake to be a function of dry matter consumption; later work supported this conclusion (13). Using the data of Ritzman and Benedict (17) and others, Leitch and Thompson (7) rejected the hypothesis that water intake could be predicted satisfactorily on the basis of dry matter consumption. They reviewed the direct effects of many high temperature environmental factors and of lactation on water intake to support their brief.

Recently, Winchester and Morris (20) found (Figure 2) water intake of cattle to be a function of dry matter consumption and ambient temperature. They found that, when water intake per unit of dry matter ingested was plotted, the ratio was constant between 10° and 40° F., then increased at an accelerated rate with rising temperature to 100° F. Unfortunately, Winchester and Morris (20) did not include the data gathered in the 10° to 40° F. temperature range in their publication. Upon regressing ratios of daily total water:dry matter intake on both d-h/day and DMAAT in the temperature zones studied (Table 1), the results were not significant

(Table 2). These results support Winchester and Morris's statement that the ratio was constant between 10° and 40° F. and extend the temperature range to 0° F. The ratio for lactating cows at the University of Saskatchewan was somewhat higher, both at 0° and 40° F., than that calculated by Winchester and Morris for European cattle in general (Figure 2). At a mean temperature of 0° F., the ratio was 4.25:1 (pounds of water per pound of dry matter) while at a mean temperature of 40° F. the ratio was 4.36:1. As mentioned previously, this ratio increase was not statistically significant.

6. *Effect of d-h/day and DMAAT on the Ratio in Pounds of Daily Total Water Intake:Dry Matter Intake during the Subsequent Day*

In the temperature range studied, neither d-h/day nor DMAAT had a significant effect (Table 2) on the ratio, in pounds, of daily total water intake:dry matter intake during the subsequent day. These results were not unexpected, since these factors did not exert a statistically significant direct effect on the daily total water:dry matter intake ratio.

7. *Effect of d-h/day and DMAAT on the Ratio of Daily Total Water Intake:Hay Dry Matter Intake*

Missouri workers (14) found that a slight increase in water consumption at low temperatures was associated with an increase in hay consumption. They indicated that the ratio of water consumption:hay consumption was constant in a temperature range of 8° to over 50° F. Similarly, in this study, upon regressing the ratio, in pounds, of daily total water intake:hay dry matter intake on either d-h/day or DMAAT, the ratios remained constant, i.e., ratio differences with temperature changes were statistically insignificant.

It has often been stated, without the support of research data, that animals consuming roughages require more water for digestive and intermediary metabolic activities than animals consuming concentrates. It would appear, initially, that inferential support for this belief was found here, since water intake increased as hay consumption increased with decreasing temperatures. This belief was tested within the temperature range studied by regressing the ratio (Y) of average daily caloric intake from hay:caloric intake from concentrates, on average daily total water intake (x) in grams. The resulting correlation was not statistically significant (d.f. = 39; r = .209), indicating that water intake was unaffected by the physical form in which calories were ingested.

8. *Effect of d-h/day and DMAAT on the Ratio of Daily Total Water Intake in Grams:Total Caloric Intake*

In an excellent literature review of water requirements for farm animals, Leitch and Thompson (7) analysed available experimental results with a view to further defining the conditions governing water requirements. Literature reviewed permitted them to establish that, in estimating requirements, total water intake must be considered; that frequency of watering may affect requirements; that milk yield or rate of production in general must be known, and that temperature has an important effect.

Using water:dry matter intake ratios rather then water:Calorie ratios they rejected by inference, as did others (10), the principle enunciated by Adolph (1) that the water requirements of all mammals are roughly 1 millilitre per Calorie of heat produced.

In this study, using lactating cows, each animal received hay *ad libitum*, concentrates according to production, and water frequently enough to overcome the adverse effects of infrequent watering. They were maintained under environmental temperatures (2° to 45° F.) where water is not required to dissipate body heat (13, 14, 15, 16, 19). Under these conditions, the average intake was 1.01 millilitre of water per Calorie of gross energy. Temperature did not affect the ratio in the range studied. The correlation between water intake and caloric intake was significant at the 2 per cent level (df = 39, r = .383).

Upon deducting the caloric and water contents of milk produced, assuming milk to be 87 per cent water and obviously over-simplifying the calculations, the ratio was still 0.96:1.

9. *Effect of d-h/day and DMAAT on the Ratio of Daily Total Water Intake: Milk Yield*

The ratio of total water intake:milk yield decreased as temperatures decreased but the correlation with either d-h/day or DMAAT was not statistically significant. Direct comparisons with results obtained by Missouri research workers (13, 14) are not possible, since their results were confounded by increases in liveweight and marked decreases in lactation during their periods of experimentation.

Water consumed must be raised to the body temperature and this necessitates the use of food energy directly or indirectly. It is hypothesized that, when cattle are watered frequently with moderately cold water, specific dynamic action (SDA) energy spares the use of productive energy for the purpose of heating water.

Large, infrequent water intakes have been shown to depress milk and butterfat yields and rates of live weight gain (5, 9). This indicates either the diversion of potential productive energy to heat production, or, less probably, that water intake is insufficient to maintain body functions at optimum levels. It is probable, however, that SDA energy could spare much of the production energy in cases where cattle were more frequently offered moderately cold water. The finding in this experiment, that water requirements increased as temperatures declined (along with a corresponding increase in feed intakes), emphasizes the importance of the methods for providing water to livestock exposed to low temperatures. If unnecessary losses in production and feed efficiency are to be avoided, continuous access to a supply of moderately warm water is desirable.

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FURTHER STUDIES ON THE PROTEIN AND ENERGY REQUIREMENTS OF YOUNG DAIRY CALVES[1]

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ABSTRACT

To confirm laboratory estimates of protein and energy requirements, 32 newborn dairy calves were fed "filled milk" diets containing 18 to 35 per cent of the total calories as protein. A comparison was made between the actual growth rates and growth rates predicted from the consumption of protein and energy. A decline in the efficiency of protein utilization did not occur until the level of dietary protein exceeded 24 per cent of the total calories. Optimum energy efficiency, measured by weight gain, was obtained at intakes below 80 digestible Cal./kg./day. At energy intakes above this level each additional digestible Cal. did not result in the predicted increment in body weight.

INTRODUCTION

The protein and energy requirements of preweanling dairy calves were estimated by laboratory techniques and found to be 65.3 mg. N and 44.7 digestible Cal. per kg. body weight per day for maintenance and 3.22 gm. N and 268 digestible Cal. per 100 gm. gain in weight (5, 6). Maynard (8) has pointed out the necessity for testing the validity of such estimates under conditions of more normal agricultural practice. This paper reports such a test.

EXPERIMENTAL PROCEDURE

Twenty-six Holstein and 6 Ayrshire calves at birth were allotted randomly within breed and sex into four groups of 8. They were muzzled and placed in individual pens bedded with wood shavings. Colostrum was fed for the first 3 days at the rate of 1.82 to 2.73 kg./calf/day, depending upon body weight and appetite.

The four "filled milk" diets shown in Table 1 were the same as those employed in another phase of this work (5). Groups 5, 6, 7 and 8 received diets 5, 6, 7 and 8 respectively. The calves were weighed weekly and growth was measured by the daily increase in body weight per unit of body weight. The fluid diets were given at the rate of 8 per cent of body weight per day in two feedings for the remainder of the first week and then at the rate of 10, 12, 14, and 14 per cent during four successive periods of 1, 2, 2, and 2 weeks, respectively.

Fresh diets were prepared twice weekly, and the whole milk used in each batch was sampled. Weekly composited samples of the whole milk and samples of the skim milk powder were analysed by standard procedures (3) for total solids, lactose, nitrogen, fat, and ash. Samples of the cerelose were analysed for moisture and the average composition of the diets was

[1] Joint contribution from Chemistry Division (No. 376), Science Service, and Animal Husbandry Division, Experimental Farms Service, Ottawa, Ont.
[2] Research Officer, Nutrition, Chemistry Division.
[3] Research Officer, Dairy Cattle, Animal Husbandry Division.

TABLE 1.—COMPOSITION OF THE DIETS

Ingredient (%)	Diet 5	Diet 6	Diet 7	Diet 8
Whole milk	66.67	66.67	66.67	66.67
Skim milk powder	—	2.30	4.62	6.91
Water	26.42	26.42	26.42	26.42
Minerals[1]	1.01	0.68	0.33	—
Cerelose	5.90	3.93	1.97	—
Vitamins[1]				
Antibiotic[1]				
Total solids (%)	14.14	14.30	14.45	14.60
Butterfat (%)	2.15	2.09	2.13	2.17
Lactose (%)	3.56	4.80	5.94	7.04
Glucose (%)	5.37	3.58	1.79	0.00
Ash (%)	1.03	1.04	1.03	1.05
Cal./kg./diet[2]	656.80	677.50	704.00	730.10
Protein (% of fluid diet)	2.02	2.78	3.55	4.34
Protein (% of total solids)	14.3	19.4	24.6	29.7
Protein (% of total calories)	18.0	24.0	29.5	34.8

[1] Same as reported previously (5)
[2] Fuel values of 9.11, 3.95, 3.76, and 5.86 Cal. per gram were used for butterfat, lactose, cerelose, and casein respectively (1).

calculated (Table 1). The average moisture content of samples of cerelose taken during the experiment was higher than that of the skim milk powder and, hence, the total solids and digestible calorie content of the diets increased slightly with each increase in skim milk powder supplementation. The higher caloric value of the lactose and protein in the skim milk powder over that of the cerelose was also partially responsible for the higher calorie content of the diets with each increase in the level of protein. These differences were later taken into consideration in analysing the data.

RESULTS AND DISCUSSION

The average growth rates of the four groups of calves are compared in Figure 1 with the Beltsville standards (7). The data indicate that in groups 6, 7 and 8 the protein and energy intakes were sufficient to promote growth superior to Beltsville standards. The growth rates of the calves in this experiment resembled those obtained in balance studies with other calves receiving the same diets at equivalent levels of feed intake (5). Average growth rates of the calves receiving diets 5, 6, 7 and 8 when the feed intake equalled 12 per cent of body weight per day were 7.9, 11.0, 13.3, and 14.5 gm. per kg. per day respectively while the respective growth rates in previous work (5) were 7.7, 11.4, 13.1, and 14.7.

Figure 2 shows the efficiency in weight gains in relation to digestible energy and nitrogen intake for each diet during the four periods. The digestible Cal. intake was calculated by using the average calorie digestion coefficient of 98.25 obtained in digestibility studies with the same diets (5). There was no significant difference in the rates of gain of groups 6, 7 and 8 when growth was put on an isocaloric basis but the growth rates of these groups were significantly higher than those of group 5 by analysis of variance ($P < 0.01$).

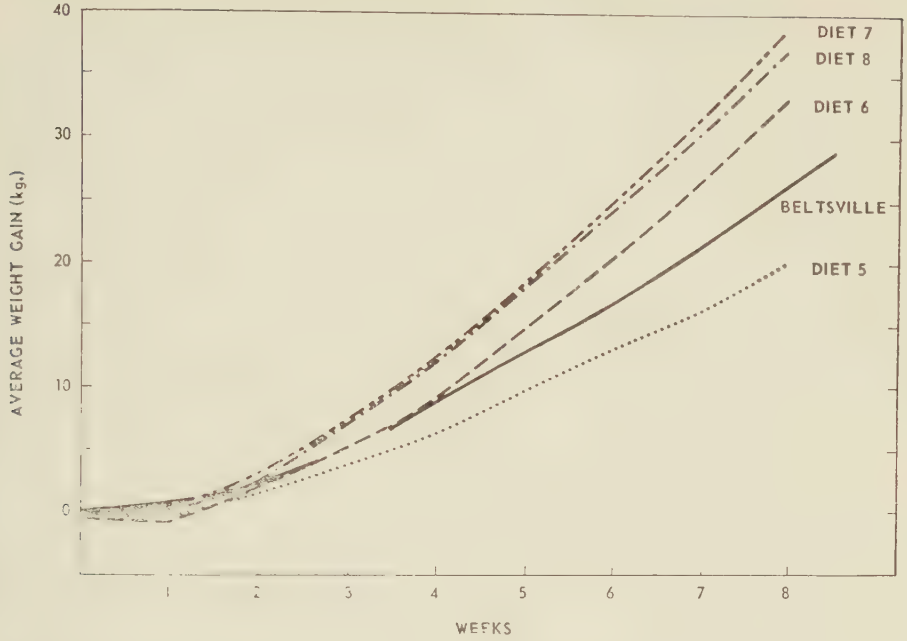

FIGURE 1. Average growth rate of each group of calves compared with the Beltsville standards (7).

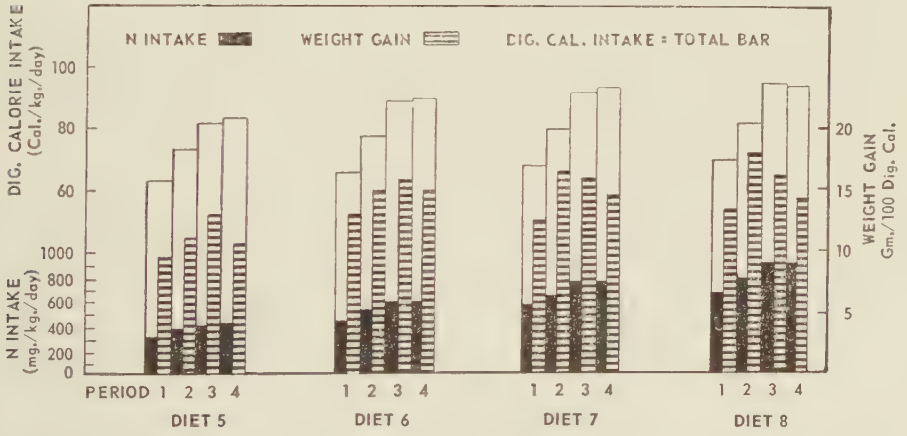

FIGURE 2. Nitrogen intake, digestible Calorie intake, and weight gains per kilogram of body weight per day for each group in each period.

Protein efficiency, or weight gain per gram of nitrogen intake, averaged 22.5, 22.5, 18.5, and 16.5 gm. for diets 5, 6, 7, and 8 respectively. It would appear, therefore, that the best results for a combination of growth and protein efficiency were obtained in this study with the second level of protein supplementation. The protein intake at this level was equivalent to 24.0 per cent of the total calorie intake or 19.4 per cent of the dry matter intake.

TABLE 2.—COMPARISON OF ACTUAL GROWTH RATES WITH THOSE PREDICTED FROM REQUIREMENTS

Diet	Period	Growth[1] energy Cal./kg./day	A.D.N./[2] mg./kg./ day	Average[3] actual wt. gain gm./kg./day	Wt. gain [4] predicted from energy gm./kg./day	Wt. gain [5] predicted from A.D.N. gm./kg./day
5	1	18.4	292	6.20	6.87	6.02
	2	28.7	341	7.66	10.71	7.36
	3	37.2	374	10.63	13.88	8.29
	4	38.6	387	8.97	14.40	8.63
6	1	20.8	410	8.49	7.76	9.28
	2	32.0	479	11.44	11.94	11.18
	3	43.9	556	14.03	16.38	13.32
	4	44.5	560	13.35	16.60	13.45
7	1	23.2	531	8.50	8.66	12.67
	2	34.8	620	13.15	12.98	15.12
	3	47.0	716	14.55	17.54	17.76
	4	47.7	724	13.45	17.80	17.98
8	1	24.6	638	9.31	9.18	15.62
	2	36.5	751	14.75	13.62	18.76
	3	49.4	872	15.32	18.43	22.08
	4	48.7	865	13.40	18.17	21.89

[1] Digestible energy intake in Cal. per kg. per day minus 44.7.

[2] The apparent digestible nitrogen intake was calculated using digestibility figures of 94.5, 95.9, 97.2 and 97.7 for diets 5, 6, 7 and 8 respectively (5).

[3] Average of weight gains of eight calves for each period.

[4] Using 268 Cal. required above maintenance per 100 gm. of gain (5).

[5] Using 3.22 gm. of nitrogen balance per 100 gm. of gain (5). Nitrogen balance was calculated using the equation $(NI \times \frac{BV}{100})$-MFN-EN.

[The total fecal nitrogen excretion of calves fed "filled milk" diets was previously shown to be less than that of calves fed nitrogen-free diets (5). Thus the true digestibility of the whole milk and the skim milk protein was calculated as 100 per cent and all fecal nitrogen was considered to be of metabolic origin or MFN = NI-ADN. EN =65.3 mg./kg./day (6) and a biological value of 89.3 was used for all diets (5)].

The growth rates in the present experiment were compared in Table 2 with the growth rates predicted from requirements set forth previously (5). The growth rates of the calves in most groups agreed with those predicted from either the protein or energy intake depending upon which was the limiting factor. In groups 5 and 6, periods 2, 3, and 4, were protein intake controlled growth, the total actual growth over the 6 weeks was 112 and 102 per cent respectively of that predicted from data on protein requirements. In period 1 of groups 5 and 6 the growth rates predicted from consumption of protein and energy were approximately equal and the actual growth rate was in agreement with both. The dietary protein level of diets 7 and 8 was relatively high and energy intake was expected to control growth. In this case the digestible energy consumption during periods 1 and 2 was within the range previously used to estimate energy requirements (up to 80 Cal./kg./day) (5), and the growth rates compared closely with predicted values. The digestible energy intake in periods 3 and 4 averaged 93 Cal./kg./day and the growth rates were lower than the predicted values. It is well known that as calves grow older more energy is stored per unit of body gain, but this is usually more noticeable with higher planes of caloric intake (2,9). Moulton *et al.* (9) observed that the fat content of the bodies of newborn

calves was 3.6 per cent and that after 3 months on low, medium and high planes of nutrition it rose to 4.4, 7.3 and 9.7 per cent, respectively. No carcass analysis or other experimental evidence was obtained in the present study to show why the additional energy supplied during the latter weeks did not result in the expected rate of gain. In view of the above observation, however, it would appear possible that more energy than predicted may have been stored as fat.

In regard to protein requirements it may be concluded that the growth rates in the present study compare closely with those calculated previously (5). Weight gains in relation to energy intake agree with those calculated from requirements up to 4 weeks of age or for digestible calorie intakes up to 80 Cal. per kg. per day. However, if calves are fed to exceed the Beltsville standards, higher digestible calorie intakes per unit of gain may be required after the fourth week.

ACKNOWLEDGEMENT

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WOOL GROWTH IN SHEEP AS AFFECTED BY THE ADMINISTRATION OF CERTAIN SEX HORMONES[1]

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ABSTRACT

Three experiments were conducted to determine the effect of certain sex hormones on wool growth in sheep. The administration of estradiol intramuscularly caused a significant ($P < .01$) reduction in the average weight of clean wool and fibre length obtained from tattooed areas. In addition, this treatment reduced average thyroid weight, but increased pituitary and adrenal weights. It is suggested that the reduction in wool production resulted from a lowered thyroid activity and from adrenal cortical stimulation.

The use of diethylstilbestrol orally produced the same general effects as estradiol but to a lesser degree.

The administration of a single implant of diethylstilbestrol (12 mg.) to ewe lambs had no effect on wool growth. However, a second implant, administered 3 months after the first, resulted in a significant decrease in the average weight of clean wool from a measured area when compared to the controls.

Testosterone significantly ($P < .05$) increased the weight of clean wool when the sheep were treated with relatively high doses (up to 175 mg.) during the first part of the experiment and lower doses (75 mg.) during the latter part. However, in another experiment where 125 mg. per head was used throughout the trial no response in wool growth was obtained. In the latter experiment there was some indication that thyroid activity was stimulated, suggesting that the testosterone dose was at the lower threshold level for wool growth.

Progesterone given intramuscularly had no effect on wool growth in this study.

INTRODUCTION

Female sex hormones are being used extensively as implants and in rations for fattening lambs and beef cattle in the United States. The inclusion of this material in rations for beef cattle in Canada was approved in 1956 and has been used extensively since that time. This treatment causes certain physiological disturbances in the animal (2), but since the animal is going to slaughter these changes are of little practical significance. In addition, it has been reported by Ellis *et al.* (3) that the edible portions of the carcass appear to be unaffected. However, there is only a limited amount of experimental data available on the effect of sex hormones on wool growth. Madsen (10) studied the wool production of feeder lambs implanted with one pellet (12 mg.) of diethylstilbestrol and fed a fattening ration for 3 months. Wool obtained from tattooed areas showed no significant differences between the treated and untreated groups in clean weight, fibre thickness, or fibre length. Houssay (6) reported that estradiol benzoate had an inhibitory effect on hair growth in mice, while Ferguson (4) noted that orchidectomy had no effect on wool growth.

[1] Joint contribution from the Division of Animal Husbandry, Experimental Farms Service, and Health of Animals Division, Production Service.

Wool is a valuable by-product of finished lamb; consequently it is important to know how the wool is affected by hormone treatments used to influence gain. In view of this, some experiments were carried out at the Experimental Farm, Lethbridge, Alberta, to determine the effect of certain sex hormones on wool growth.

MATERIALS AND METHODS

Experiment 1 (1955)

This experiment was designed to study the effect of progesterone and testosterone on wool growth in sheep. Twelve grade Corriedale yearlings were divided into three equal lots (2 ewes and 2 wethers) and group-fed an adequate ration. The animals received their first hormone treatment in May and the experiment was completed in October. The treatments were as follows:

Lot 1—Received 250 mg. per head of progesterone intramuscularly at 14-day intervals for the first half of the experiment and 125 mg. thereafter.

Lot 2—Received testosterone doses of 50, 125, 175, 175, and 125 mg. per head intramuscularly at 14-day intervals during the first part of the experiment. Thereafter the dosage was reduced to 75 mg. per head.

Lot 3—Control.

Wool samples were taken from tattooed areas on the right shoulder of each sheep at 28-day intervals and analysed for clean weight.

Experiment 2 (1955)

This experiment was designed to study the effect of diethylstilbestrol implants on wool growth in feeder ewe lambs (grade Corriedales). Two lots of 3 lambs each were used. Lot 1 received a 12 mg. implant in the neck on January 12 and a second implant on May 11, while lot 2 received no treatment. The sheep were individually fed a growing ration with feed intake being the same for all sheep to reduce individual variation in wool growth.

Wool samples were taken from tattooed areas on the right shoulder of each sheep at 28-day intervals and analysed for clean weight.

Experiment 3 (1956)

Fifty-six yearling sheep (grade Corriedales), half of which were ewes and half wethers, were used to study further the effect of certain sex hormones on wool growth. The animals were placed on feed for one 28-day period before the hormone treatments began and wool samples were collected at the end of this period. The sheep then were divided into four lots of 14, on the basis of weight of clean wool, fibre length, fibre thickness, and body weight. The ewes and wethers were distributed equally among the lots.

The hormone treatments were as follows:

Lot 1—Received 4 mg. per head of estradiol (veterinary grade in depot form) intramuscularly at 14-day intervals.

Lot 2—Received 3 mg. of diethylstilbestrol (stilbosol)* daily mixed with the concentrate.

Lot 3—Received 125 mg. of testosterone intramuscularly at 14-day intervals.

Lot 4—Control.

* Diethylstilbestrol "Premix" (Eli Lilly and Co., Toronto).

The sheep were individually fed a complete ration, with feed intake being the same for all sheep to reduce individual variation in wool growth. The average daily consumption was 1.25 lb. of hay and 1.0 lb. of grain with deviations between lots of not more than .02 lb. The concentrate was fed in pelleted form and the roughage as chopped hay. To collect wool growth data, duplicate areas (2 sq. cm.) were tattooed on the right shoulder of each sheep, and samples were collected from these areas at 28-day intervals. These samples were analysed for clean weight, fibre length, and fibre thickness. The hormone treatments were continued for five wool-collection periods totalling 140 days.

At the conclusion of the experiment all animals were slaughtered and the thyroid, pituitary, and adrenal glands were removed and weighed immediately.

RESULTS AND CONCLUSIONS

Experiment 1

The average weights of clean wool as affected by the administration of certain sex hormones are shown in Table 1.

TABLE 1.—WOOL GROWTH FROM MEASURED AREAS (4 SQ. CM.) AS AFFECTED BY THE ADMINISTRATION OF CERTAIN SEX HORMONES

Growth period	Average weight of clean wool (mg.)		
	Progesterone	Testosterone	Control
May – June	97.2	104.8	90.6
June – July	95.8	104.0	93.2
July – August	105.6	129.1	102.3
August – September	111.5	137.2	103.8
September – October	119.1	149.1	99.8
October – November	98.6	137.3	90.6
Lot average	104.6	126.9**	96.7

** Significantly higher than the controls ($P < .01$)

The results indicate that testosterone, at the levels used in this experiment, had a stimulatory effect on wool production. Testosterone significantly ($P < .01$) increased the average weights of clean wool produced from tattooed areas by approximately 30 per cent. On the basis of the gland data from Experiment 3 it would appear that the testosterone treatment stimulated thyroid activity, which in turn increased wool growth.

Progesterone had no significant effect on wool growth under these conditions.

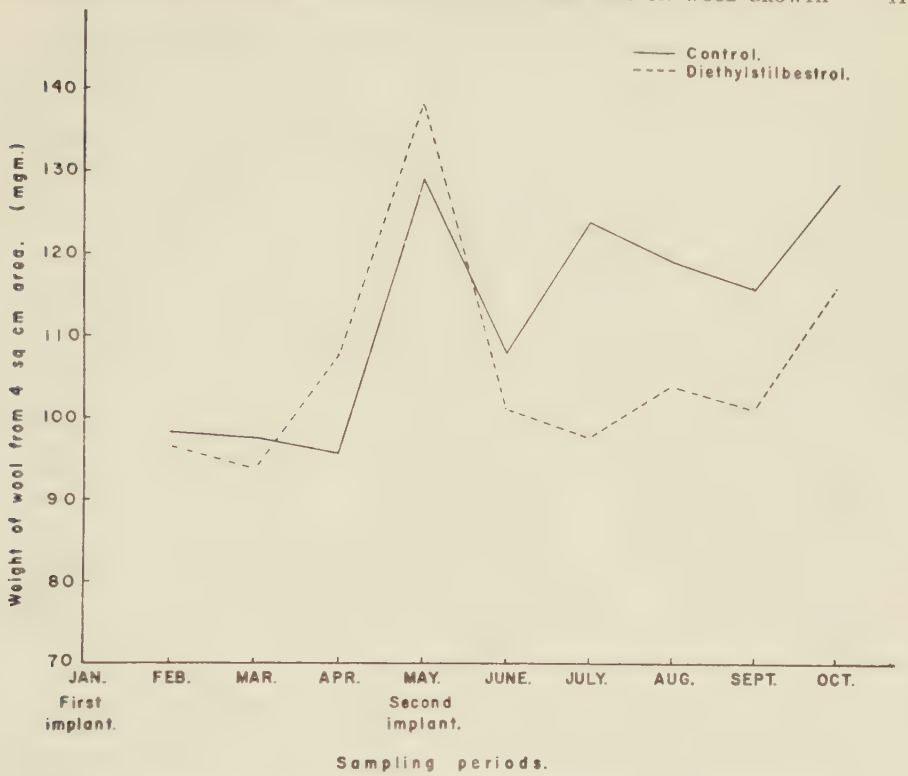

FIGURE 1.—Periodic wool growth as affected by implants of diethylstilbestrol.

Experiment 2

The effect of diethylstilbestrol implants on wool growth in ewe lambs is shown in Figure 1.

During the period from January 12, following the first implant of diethylstilbestrol, until May 11, there were no significant differences in the average weights of clean wool produced from the tattooed areas. However, the wool samples taken after the second implant on May 11 indicated that growth had been depressed below the level of the control lot. The weights of wool obtained from the following four sampling periods were significantly lower ($P < .05$) in the implanted lot than in the control. The gland data from Experiment 3 indicate that the thyroids were decreased in weight by both estradiol ($P < .01$) and diethylstilbestrol, suggesting a lowered thyroid activity (8) with a resultant depression in wool growth (11). The average body weights for the diethylstilbestrols treated and the control lots are shown in Figure 2. Increased body gains were obtained in the treated lot when compared with the control during the first part of the experiment and this difference was maintained during most of the latter part.

Experiment 3

Data relative to body weights are shown in Table 2. There appeared to be some stimulation as a result of the oral administration of diethylstil-

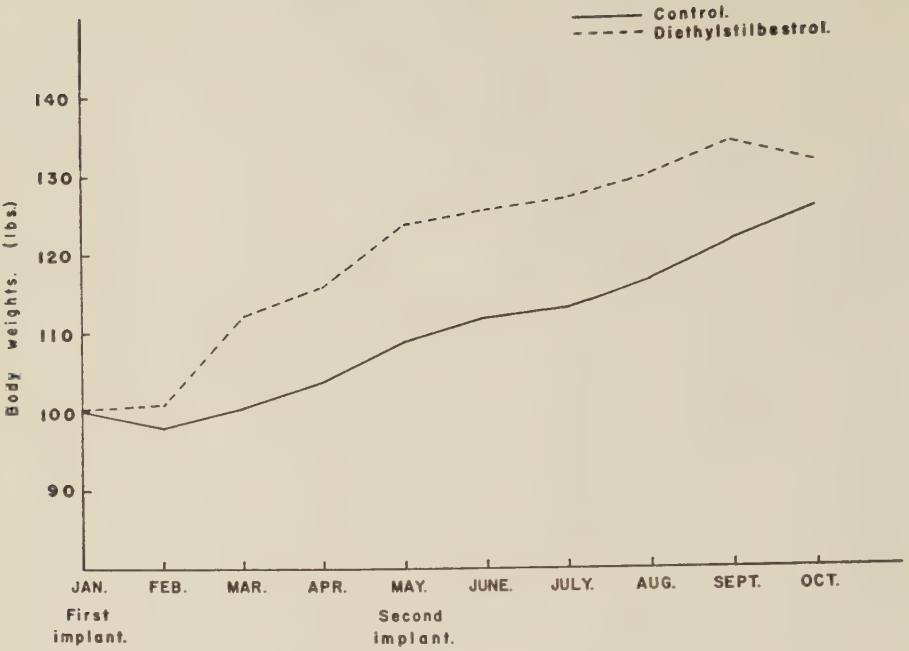

Figure 2.—Body weights as affected by implants of diethylstilbestrol.

bestrol. However, an analysis of covariance of the ewe body weights at the beginning and at the conclusion of the trial indicated that there were no significant differences between the various treatments.

With wethers, there were no differences in average body weights at the beginning of the trial but significant differences in weights were obtained as a result of the treatments. Those sheep receiving estradiol and diethylstilbestrol were significantly heavier ($P < .01$) than the controls.

The use of testosterone had no effect on body weight gains in this experiment.

TABLE 2.—AVERAGE INITIAL AND FINAL BODY WEIGHTS AND GAINS OF SHEEP RECEIVING CERTAIN SEX HORMONES

	Initial weight (July 19)	Final weight (December 19)	Weight gain
	lb.	lb.	lb.
Ewes			
Stilbestrol (oral)	99.4	114.7	15.3
Estradiol	99.4	112.1	12.7
Testosterone	93.7	105.3	11.6
Control	101.8	113.4	11.6
Wethers			
Stilbestrol (oral)	104.3	118.3**	14.0
Estradiol	103.1	114.7**	11.6
Testosterone	104.3	114.1	9.8
Control	104.7	113.1	8.4

** Significantly higher than the control ($P < .01$)

WOOL PRODUCTION

Weights of Clean Wool

The average weights of clean wool taken from tattooed areas at 28-day intervals are shown in Table 3.

TABLE 3.—AVERAGE WEIGHTS OF CLEAN WOOL FROM TATTOOED AREAS AS AFFECTED BY THE ADMINISTRATION OF CERTAIN SEX HORMONES

Period ending	Treatment				Period average
	Oral Stilbestrol	Estradiol	Testosterone	Control	
Ewes	Weights of clean wool (mg.)				
August 31, 1956	100.0	89.4	106.2	101.8	99.4
September 28, 1956	93.4	77.2	96.2	102.2	92.4
October 26, 1956	81.9	75.8	93.0	90.6	85.3
November 23, 1956	77.5	73.3	83.6	84.0	79.6
December 21, 1956	82.0	70.5	88.4	85.2	81.5
Lot averages	87.0**	77.2**	93.5	92.8	
Wethers					
August 31, 1956	90.9	90.3	100.8	107.2	97.3
September 28, 1956	82.7	78.7	90.3	95.2	86.7
October 26, 1956	82.6	77.2	81.1	85.0	81.4
November 23, 1956	76.3	74.1	72.4	73.4	74.0
December 21, 1956	78.7	75.8	72.9	78.0	76.4
Lot averages	82.2	79.2*	83.5	87.8	

** Significantly lower than the controls ($P < .01$)
* Significantly lower than the controls ($P < .05$)

Significant reductions ($P < .01$) in the average weights of clean wool were obtained from ewes treated with estradiol and diethylstilbestrol and from wethers ($P < .05$) when treated with estradiol. These results with female sex hormones confirm those obtained in a preliminary trial at this Farm using diethylstilbestrol implants and also agree with the work of Houssay (3). In the present experiment wool growth in the ewes declined more rapidly when estradiol was administered intramuscularly than when diethylstilbestrol was given orally. The testosterone treatment produced no effect on wool growth in either sex. This is not in agreement with previous results, although the dosage levels in the earlier trial were somewhat higher and may account for the differences in response.

Fibre Lengths

The average fibre lengths obtained during both the pre-experimental and the experimental periods are shown in Table 4. With both ewes and wethers it was found that those lots treated with estradiol showed a significant ($P < .01$) decrease in average fibre lengths. A significant ($P < .05$) reduction also was obtained with the ewes when diethylstilbestrol was used. This is in general agreement with the results of Maqsood (11) who reported a decrease in fibre length due to mild hypothyroidism.

TABLE 4.—AVERAGE FIBRE LENGTHS AS AFFECTED BY THE ADMINISTRATION OF CERTAIN SEX HORMONES

	Treatment				Period average
	Stilbestrol	Estradiol	Testosterone	Control	
	Average fibre lengths (mm.)				
Ewes					
Pre-experimental	10.7	10.3	10.8	10.4	
August 31, 1956	10.3	10.1	11.4	11.4	10.8
September 28, 1956	9.9	9.4	10.1	10.3	9.9
October 26, 1956	9.7	9.3	10.2	10.0	9.8
November 23, 1956	9.4	9.0	10.0	9.8	9.6
December 21, 1956	9.6	8.5	9.8	9.4	9.3
Lot average	9.8*	9.3**	10.3	10.2	
Wethers					
Pre-experimental	10.7	10.1	10.5	10.6	
August 31, 1956	10.3	9.5	10.5	10.4	10.2
September 28, 1956	9.9	8.3	9.5	9.7	9.4
October 26, 1956	9.9	8.6	9.2	9.9	9.4
November 23, 1956	9.7	8.6	8.9	9.3	9.1
December 21, 1956	9.6	7.9	8.1	8.6	8.6
Lot average	9.9	8.6**	9.2	9.6	

* Significantly lower than the controls ($P < .05$)
** Significantly lower than the controls ($P < .01$)

TABLE 5.—AVERAGE FIBRE THICKNESS AS AFFECTED BY THE ADMINISTRATION OF CERTAIN SEX HORMONES

	Treatment				Period average
	Stilbestrol	Estradiol	Testosterone	Control	
	Average fibre thickness (microns)				
Ewes					
Pre-experimental	24.9	23.3	24.8	24.2	
August 31, 1956	24.8	24.5	27.4	25.8	25.5
September 28, 1956	23.8	23.3	26.7	25.8	24.9
October 26, 1956	23.0	23.8	28.5	26.5	25.4
November 23, 1956	23.7	25.1	27.2	25.7	25.4
December 21, 1956	23.5	23.6	26.2	24.2	24.4
Lot average	23.8	24.1	27.2	25.6	
Wethers					
Pre-experimental	25.2	24.2	24.7	24.2	
August 31, 1956	24.4	24.5	24.3	25.1	24.6
September 28, 1956	22.9	22.7	23.2	23.5	23.1
October 26, 1956	23.5	23.9	24.0	23.6	23.8
November 23, 1956	23.9	24.2	23.5	22.9	23.6
December 21, 1956	22.6	23.7	21.8	22.2	22.6
Lot average	23.5	23.8	23.4	23.5	

Fibre Thickness

The average fibre thickness obtained during the pre-experimental and experimental periods is shown in Table 5. The data from the ewes in each lot indicate that there was little change in the average fibre thicknesses obtained at the different samplings. However, in the wethers there was a decrease in fibre thickness in each group. When the data were analysed by covariance to adjust for differences in the initial thicknesses, no differences were obtained between treatments.

Gland Weights

The average warm weights of the thyroid, pituitary, and adrenal glands are shown in Table 6.

TABLE 6.—THE AVERAGE WEIGHTS OF CERTAIN GLANDS AS AFFECTED BY THE ADMINISTRATION OF SEX HORMONES

Treatment	Gland weights (gm.)		
	Thyroid	Adrenal	Pituitary
Ewes			
Stilbestrol	3.27	3.08	0.64
Estradiol	2.88*	3.53**	0.92**
Testosterone	4.37	2.65	0.61
Control	3.72	2.79	0.61
Wethers			
Stilbestrol	3.00	3.09	0.87**
Estradiol	3.01*	4.02**	0.84**
Testosterone	4.10	3.01	0.74
Control	3.57	3.04	0.64

* Significantly lower than the controls ($P < .05$)
** Significantly higher than the controls ($P < .01$)

The administration of estradiol significantly ($P < .05$) decreased the average weight of thyroids in both ewes and wethers when compared with the controls and, as indicated previously, a significant decrease also occurred in the weights of clean wool produced by these sheep. Lever and Vlijm (8) have reported that thyroid weight was a satisfactory method for determining thyroid activity when this activity was low. Maqsood (11) and Slen* have shown that wool growth was reduced when a goitrogen was administered. Using this work as a criterion it would appear that, in the present experiment, estradiol depressed thyroid activity, which in turn reduced wool production. It also would appear that diethylstilbestrol administered orally had a similar effect. Although the reduction in thyroid weight was not significant the decrease in wool growth would indicate that a response was obtained.

* *Unpublished data.* Wool Research Laboratory, Lethbridge, Alta.

It was noted that testosterone treatment increased thyroid weights somewhat (although not significantly), which might indicate an increased thyroid activity, although there was no response in wool weights in this experiment. However, in Experiment 1, where a higher dosage level was used, a significant increase in wool growth was obtained and would appear to confirm the fact that the thyroid was involved (5, 11). Histological examination of the thyroid glands from sheep treated with testosterone showed that the thyroid follicles were larger and more numerous than those of the controls, which would suggest an increase in activity. Johnston *et al.* (7) have reported results contrary to these in their experiments on adult ewes. They obtained a significant reduction in thyroid weights from ewes injected with 50 mg. of testosterone twice weekly. However, Burris *et al.* (1) noted that the thyroid glands from beef animals were larger in the testosterone-treated groups than in the controls.

The average weights of the pituitary and adrenal glands from both ewes and wethers were increased significantly ($P < .01$) by the estradiol treatment in this experiment. Clegg and Cole (2) found that the pituitaries and adrenals from beef steers and heifers were significantly hypertrophied ($P < .01$) after the animals were each treated with an implant of 60 mg. of stilbestrol. However, the ACTH content of the pituitaries of the treated steers was not significantly different from that of the untreated animals (none was reported for the heifers). Ewe and wether lambs treated with stilbestrol implants (12 and 24 mg.) also were used in the same experiment. Although no endocrine gland data were collected, differential blood counts were obtained and there was a marked eosinopenic response in both groups. These workers also stated that, since a depression in blood eosinophils was related to an increase in adrenal cortical activity stimulated by an increased secretion of ACTH, it would appear that diethylstilbestrol caused an increased release of this hormone from the ruminant pituitary, thus bringing about adrenal cortical stimulation. Linder and Ferguson (9) have shown that injections of ACTH not only reduced the number of circulatory eosinophils but seriously suppressed wool growth. From this evidence it would appear that adrenal cortical stimulation could account for some of the reduction obtained in weights of clean wool in the experiment reported in this paper. Studies now are under way to determine which glands are involved in the suppression of wool growth.

No significant responses in these glands were obtained from testosterone treatment, which is in general agreement with the results of Johnston *et al.* (7).

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THE EFFECTS ON THE ODOUR AND FLAVOUR OF THE MEAT OF FEEDING REFUSE SCREENINGS WITH A HIGH STINKWEED (*THLASPI ARVENSE* L.) CONTENT TO FATTENING CATTLE.[1]

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Canada Department of Agriculture

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ABSTRACT

Two experiments, (one at Vancouver, British Columbia, and one at the Experimental Farm, Lethbridge, Alberta), involving 44 yearling steers, were conducted to determine whether feeding refuse screenings with a high proportion of stinkweed seeds to fattening beef cattle would result in objectionable odours or off-flavours in the meat. Nine of 12 steers slaughtered immediately off screenings had a slight to strong objectionable odour in their carcasses. There were no objectionable odours in the carcasses of animals that were held off screenings for 24, 48, or 96 hours before slaughter. Two animals slaughtered immediately off screenings, and one animal held off screenings for 48 hours before slaughter had off-flavours in the meat when cooked.

Many thousands of tons of refuse screenings are available in Canada each year from terminal grain elevators, flour mills, and seed-cleaning plants. Most of these screenings are used as feed for cattle, sheep, and other livestock. However, many lots of screenings contain appreciable amounts of weed seeds such as stinkweed (*Thlaspi arvense* L.) that may impart an objectionable odour and or flavour to the meat of animals. A number of beef carcasses are condemned annually in meat-packing plants by veterinary inspectors because of odours that are thought to be caused by the animals eating certain weed seeds.

Richardson and Dickson (3) reported that lambs fed alfalfa hay and wheat screenings that contained approximately 70 per cent weed seeds and inert matter produced soft, flabby lean, and greasy fat tissues as compared with those fed wheat. The meat from the screenings-fed lambs had an objectionable odour and flavour when compared with the wheat-fed lambs. When wild turnip, tumbling mustard, and fan-weed seeds, individually, comprised 16 to 60 per cent of the grain ration, the fanweed and wild turnip seeds caused an objectionable odour and flavour to the fat and lean meat, but tumbling mustard gave a more desirable meat than wheat.

Wood[7] found no evidence of objectionable odours or off-flavours in the meat of cattle full fed on pelleted refuse screenings up to the day of slaughter.

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[1] Joint contribution from the Experimental Farms Service, Production Service, and Marketing Service.
[2] Experimental Farm, Lethbridge, Alta.
[3] Livestock and Poultry Production Division, Production Service, Vancouver, B.C. (now at Edmonton, Alta.)
[4] Plant Products Division, Production Service, Vancouver, B.C.
[5] Livestock and Livestock Products Division, Marketing Service, Lethbridge, Alta.
[6] Livestock and Livestock Products Division, Marketing Service, Vancouver, B.C.
[7] Wood, A. J., Univ. British Columbia. *Personal communications.* 1957.

Experiment No. 1

PROCEDURE

Twenty partly-finished, yearling steers, weighing between 800 and 1000 lb., were placed on feed in a commercial feedlot near Vancouver, British Columbia, in July, 1956, and full fed refuse screenings containing a higher-than-normal content of stinkweed seeds. These screenings contained 12.25 per cent stinkweed seeds, 2.4 per cent wild mustard seeds, and 1.8 per cent other injurious weed seeds (1). The results of a number of analyses of refuse screenings from terminal elevators showed that the average stinkweed seed content was approximately 8 per cent. The screenings were fed in the unground form. The steers consumed about 10 lb. per head daily. Some molasses and grain chaff were mixed with the screenings to induce the cattle to consume greater amounts of screenings. During the course of the experiment it was noted that many weed seeds passed through the animals undigested.

After the steers had been on feed for approximately 30 days, they were slaughtered. Six of these animals were slaughtered immediately off the screenings, and 14 were held off the screenings for a period of 48 hours before slaughter. Each animal was checked for objectionable odours when slaughtered, and the carcasses were checked after having hung in the cooler for 72 hours.

RESULTS AND DISCUSSION

The information concerning odours in the freshly-slaughtered and the cooled carcasses is shown in Table 1. Four of the six carcasses of animals slaughtered immediately off the screenings had objectionable odours. These carcasses were condemned by the veterinary inspectors. This finding is not in agreement with that of Wood* who found no objectionable odours in the carcasses of cattle fed refuse screenings up to time of slaughter. However, in the studies carried out by Wood, the screenings were fed in the pelleted form. It is possible that the grinding and pelleting process generated sufficient heat to volatilize some compounds present in weed seeds that cause objectionable odours. The screenings used by Wood contained more than 16 per cent stinkweed seeds. None of the 14 animals after being held off screenings for a period of 48 hours before slaughter had objectionable odours in its carcass.

Experiment No. 2

PROCEDURE

Twenty-four partly-finished, yearling steers of predominantly Hereford breeding and weighing approximately 800 lb. each were divided at random into two lots of 12. They were placed on feed in June, 1957, at the Experimental Farm, Lethbridge, and were fed the following ration:

Lot 1—Grass hay plus finely-ground refuse screenings.
Lot 2—Grass hay plus finely-ground and pelleted refuse screenings.

The refuse screenings were the same as those fed during Experiment No. 1, except that 10 lb. of cane molasses were added to each 90 lb. of screenings. Hay was restricted to approximately 5 lb. per head daily, and the screenings were fed *ad libitum* with the restriction that both lots consumed the same total amount of screenings on a per head basis.

*Wood, A. J., Univ. British Columbia. *Personal communications.* 1957.

TABLE 1.—OBJECTIONABLE ODOURS AND OFF-FLAVOURS NOTED IN THE CARCASSES AND MEAT OF BEEF STEERS FED HIGH STINKWEED-CONTAINING SCREENINGS WHEN SLAUGHTERED IMMEDIATELY OFF SCREENINGS AND WHEN HELD 24, 48, AND 96 HOURS OFF SCREENINGS BEFORE SLAUGHTER

Hours off screenings before slaughter	No. animals	Av. hot carcass weight (lb.)	Av. carcass grade[1]	No. with objectionable odours			No. with off-flavour when cooked
				in the hot carcass	in the cold carcass	when cooking	
EXPERIMENT NO. 1							
0	6	485	B	4	4	—	—
48	14	553	A⁻	0	0	—	—
EXPERIMENT NO. 2							
Lot 1—Screenings ground							
0	3	543	A⁻	2	2	1	1
24	3	505	A⁻	0	0	0	0
48	3	490	B	0	0	1	1
96	3	499	B	0	0	0	0
Lot 2—Screenings pelleted							
0	3	487	B	3	2	1	1
24	3	501	B	0	0	0	0
48	3	541	B	0	0	0	0
96	2	528	B	0	0	0	0

[1] A—*Choice*, B—*Good* (2)

The steers were on feed for 9 weeks. The average daily feed consumption during that period was 4.8 lb. of hay and 11.3 lb. of screenings.

One steer in lot 2 died from bloat 12 days after being put on feed.

Three steers, picked at random from each lot, were slaughtered immediately off feed, and 3 from each lot after screenings were withheld for periods of 24, 48, and 96 hours. (In lot 2, because of one death, only 2 steers were slaughtered after being off screenings 96 hours). Hay and ground oats were fed to the latter groups during the period that no screenings were fed. Each animal was checked for objectionable odours when bled, when opened, and after its carcass had hung in the cooler for 24 to 48 hours. The 10th- and 11th-rib section was removed from one side of each carcass and subjected to cooking tests (boiling, frying, and roasting). The rib sections were checked for objectionable odours when cooking, and for off-flavours when cooked. In each case a minimum of two people checked the carcasses for odours and the meat for off-flavours.

RESULTS AND DISCUSSION

The information concerning odours in the freshly-slaughtered and the cooled carcasses and in the cooked meat is shown in Table 1. With one exception, there were no objectionabe odours or off-flavours in the meat when the animals were held off screenings for a period of 24 hours or longer before slaughter. Even in the case of those slaughtered immediately off screenings, the odours and off-flavours were not pronounced. The reason for one steer, after being held off screenings for 48 hours before slaughter, having an objectionable odour and off-flavour in its meat when cooked is not known. It may be that this steer consumed greater quantities of screenings than the other steers. It also may have been the result of individual variation among animals in their ability to metabolize the compounds in weed seeds that cause the objectionable odours and off-flavours.

Degree of finish, as evidenced by carcass grade, had no apparent influence on the presence or intensity of odour or off-flavour in the meat. There were insufficient differences to suggest that the pelleting process had any effect on the odours or off-flavours from the resulting meat. However, since the odours in the meat from the steers in Experiment No. 2 were less pronounced than in those in Experiment No. 1, this might indicate that the grinding process volatilized some of the odour-producing compounds, or that during the storage of the screenings for one year some of these compounds volatilized or changed.

All the meat from the animals in Experiment No. 2 was sold to the local trade and no unfavourable reports were received from customers. It was felt by those handling the meat that it was slightly "softer" than meat from grain-fed steers.

Since in normal commercial slaughtering cattle are off feed for a period of at least 24 hours before slaughter, it seems unlikely that feeding refuse screenings, with weed seeds similar to those present in these two experiments, would cause off-flavours in the resulting meat. However, the fact remains that a number of cattle slaughtered each year have pronounced objectionable odours in their meat which are thought to be caused by the animals eating weed seeds. Although the refuse screenings used in these experiments contained a higher-than-normal amount of stinkweed seeds, it is possible that screenings available on some farms have a higher stinkweed seed content than those used in these experiments. It is possible also that weed seeds other than stinkweed may cause objectionable odours in the meat.

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SHEARLING AND SECOND-YEAR CLEAN FLEECE WEIGHTS AS AN INDEX OF WOOL PRODUCTION IN THREE BREEDS OF RANGE SHEEP[1]

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ABSTRACT

The relationship of shearling and second-year clean fleece weight to total wool production, i.e., first 5 years of life, was analysed in three breeds of range sheep (Canadian Corriedale, Rambouillet, and Romnelet) to determine its usefulness in selection for increased wool production.

A correlation of +.67 ($p<.01$) between shearling clean fleece weight and the sum of the four mature fleece weights was obtained in the three breeds studied. When the first mature weight (second fleece) was correlated with the total weight of the three subsequent fleeces, the correlation was increased significantly ($p<.01$). Consequently, the second fleece appeared to be a more reliable estimate of lifetime production than shearling weight. No breed differences in these correlations were found when lifetime production was compared to shearling or to second-year fleece weights. The regression coefficients of lifetime production on shearling fleece weight showed that a shearling ewe which produced 1.0 lb. of clean wool above the average produced approximately 3.0 lb. more than the average during her productive life.

Shearling fleece weight was found to represent 83, 77, and 80 per cent of the maximum mature fleece weight in the Canadian Corriedale, Rambouillet, and Romnelet, respectively. No breed differences were observed in this relationship.

The repeatability of annual clean fleece weight was found to be .93, .83, and .76 for the Rambouillet, Romnelet, and Canadian Corriedale, respectively.

INTRODUCTION

Clean fleece weight is recognized by many research workers as the most effective single characteristic on which to base selection for increased wool production. Since the selection of replacement stock must be done at a relatively early age, the earliest possible assessment of the wool-producing ability is of practical significance. Lambert *et al.* (4) and Pohle (8) found marked relationships between weanling and shearling fleece traits and concluded that weanling fleece could be used for preliminary selection.

In order to obtain maximum wool improvement, selection must be based on the most accurate assessment of the animal's wool-producing ability. The amount of clean wool produced is determined largely by fibre length, fibre thickness, and number of fibres per unit of skin area. The latter two are known to undergo considerable increases during the first year of life (1,7). Consequently, it is only at the end of the first year of life that the wool production may be considered to be more or less representative, both qualitatively and quantitatively, of the wool grown during the years of maturity. However, to make an early selection of future breeding animals, it is necessary to use the first fleece obtained,

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and for this reason research workers have directed their attention toward the relationship between shearling fleece characteristics and mature production.

A number of workers have studied the repeatability of grease fleece weights to determine the relation between successive fleeces from the same sheep. Lush and Jones (6), Rasmussen (9), and Wolf (13) have obtained correlations ranging from .51 to .62 between successive fleece weights in a number of breeds. Gärtner and von Ungern-Sternberg (2), Terrill (11), and Wright and Stevens (14) reported correlations of about .60 between shearling fleece weights and lifetime production. It was concluded generally that the shearling fleece weight was a useful index of total production. With the exception of Hill (3), who obtained correlation of .51 and .70 between successive clean fleeces from the same sheep, little information is available on this relationship based on clean fleece weights.

The present study was undertaken to determine the relationship between shearling and second-year clean fleece weight to mature wool production in three breeds of sheep maintained under range conditions in Western Canada. The data were adjusted for certain environmental factors so that more reliable information might be obtained on the usefulness of shearling and second fleece weight in selection for increased wool production.

MATERIALS AND METHODS

Annual clean fleece weights were obtained from ewes selected as replacement stock for the Canadian Corriedale, Rambouillet, and Romnelet breeds of sheep. All three breeds were maintained under range conditions. The ewes which were born in 1945, 1947, and 1948, and had fleece records for 5 to 7 consecutive years, were selected for analysis. Thus, for each breed three separate series of data were available corresponding to the birthdate of the ewes. In the subsequent discussion these will be referred to as the Z (1945), B (1947), and C (1948) series. Only a small proportion of these ewes had records up to the seventh year of age, whereas data were available for 5 consecutive years for about 64 per cent of the ewes. Consequently, the length of useful life was assumed to be 5 years and lifetime production was assessed on this basis.

The amount of clean wool in the fleece was determined by drawing a representative sub-sample of about 200 grams from each fleece at shearing time. This determination was made in accordance with standard laboratory procedure (12).

All shearling fleece weights were adjusted to 365 days of growth, while the mature fleece weights were adjusted to a single-pregnancy, single-lactation basis. The adjusted data were subjected to correlation and regression analyses as outlined by Snedecor (10).

RESULTS AND DISCUSSION

Clean Fleece Weights by Breed and Series

The clean fleece weights by breed and series are shown in Table 1 to indicate the average production values obtained in this study.

TABLE 1.—AVERAGE CLEAN FLEECE WEIGHT BY BREED AND SERIES

Breed	Series	No. of fleeces	Age (years)				
			1	2	3	4	5
			(lb.)				
Rambouillet	Z	10	3.81	4.99	4.93	5.07	5.14
	B	44	4.19	5.29	5.40	5.43	5.09
	C	18	4.25	5.55	5.52	5.17	4.98
Average		72	4.15	5.31	5.36	5.31	5.07
Romnelet	Z	18	4.46	5.69	5.74	5.92	5.90
	B	28	4.47	5.62	5.62	5.19	5.09
	C	24	4.59	5.82	5.73	5.64	5.50
Average		70	4.51	5.71	5.69	5.53	5.44
Canadian Corriedale	Z	7	4.09	5.06	4.94	5.17	5.02
	B	36	4.09	5.06	4.97	4.97	4.74
	C	16	4.66	5.25	5.32	5.07	4.58
Average		59	4.24	5.11	5.06	5.02	4.73

A significant increase ($p < .01$) occurred in clean fleece weights from the first to the second year of production in each breed studied. Although the follicle population normally becomes well established during the first year of life, production increased in the second year, presumably because of a continued increase in the number of fibres (7) and because body growth had lessened considerably with the result that more nutrients were available for wool growth. During the second, third, and fourth years of life clean wool production remained constant in all groups. However, in the fifth year of production significant decreases ($p < \cdot 01$) occurred in both the Rambouillet and the Canadian Corriedale breeds while a small, non-significant decrease occurred in the Romnelet.

Correlation between Shearling Fleece Weight and Lifetime Wool Production

In Table 2 the average shearling clean fleece weights are shown together with the average total production from 2 to 5 years of age for all ewes which had continuous records during that period (adjusted data). The corresponding coefficients of correlation also are listed

Significant ($p < .01$) coefficients of correlation were obtained for all groups except those for the Canadian Corriedale in the Z-series and the Rambouillet in the C-series. The coefficients within breeds were tested for homogeneity by means of the Z-test and, because they did not differ significantly, the breed averages were computed. The breed differences were not significant and consequently these averages were combined into the over-all value of $+0.67$ ($p < .01$).

The coefficient of determination indicated that approximately 45 per cent of the variability in the total mature wool production was accounted for by the observed variations in the shearling clean fleece weights. The remainder of the variability evidently resulted from sources other than the shearling weight.

TABLE 2.—AVERAGE SHEARLING AND LIFETIME (2-5 YEARS) CLEAN WOOL PRODUCTION AND THE RESULTING COEFFICIENTS OF CORRELATION

Breed	Series	No. of fleeces	Average shearling weight	Average total production (2-5 yr.)	Correlation coefficient
			(lb.)	(lb.)	
Canadian Corriedale	Z	7	4.09	20.19	+.05
	B	36	4.09	19.73	+.75**
	C	16	4.66	20.22	+.69**
All series		59	4.24	19.92	+.70**
Rambouillet	Z	10	3.81	20.32	+.64**
	B	44	4.19	21.21	+.75**
	C	18	4.25	21.23	+.42
All series		72	4.15	21.09	+.68**
Romnelet	Z	18	4.46	23.26	+.84**
	B	28	4.47	21.52	+.53**
	C	24	4.59	22.69	+.44*
All series		70	4.51	22.36	+.61**
Average of 3 breeds					+.67**

* $p<0.05$
** $p<0.01$

The significant correlations may be interpreted as an indication that high productivity in the first year will be followed by relatively high productivity during the years of maturity. However, for selection purposes the quantitative relationships are more important. These are best expressed by the coefficients of regression which are shown in Table 3, together with their standard errors. Those ewes which produced 1 lb. more wool than the average in their first year of life yielded an amount of wool ranging from 2.8 ± .4 to 3.6 ± .4 lb. above the average total production during their mature years (2 to 5 years).

TABLE 3.—REGRESSION OF TOTAL MATURE WOOL PRODUCTION (Y) ON SHEARLING FLEECE WEIGHT (X)

Breed	b_{yx}	σb
Canadian Corriedale	2.830	±.361
Rambouillet	3.598	±.453
Romnelet	2.980	±.477
All breeds	3.034	±.078

Maximum clean fleece weights, averaging 5.1, 5.3, and 5.7 lb. for the Canadian Corriedale, Rambouillet, and Romnelet, respectively, were obtained by the second year of production. On this basis, it was calculated that 83, 77, and 80 per cent of the maximum mature fleece weight was

produced in the first year of life for the three breeds, respectively. No breed differences were found in this relationship. It was evident that the shearling fleece weight represented a high proportion of the maximum weight which, if maintained throughout the sheep's productive life, would contribute to high lifetime production.

Correlation of the Second (Maximum) Fleece Weight with Lifetime (3-5 years) Production

The average second-year fleece weights and the total wool production from 3 to 5 years of age, inclusive, by breed and series, are shown in Table 4. The corresponding coefficients of correlation also are included.

The coefficients of correlation were significant except for the Z-series in the Rambouillet breed. They were tested for homogeneity within breeds and it was found that only the coefficient obtained in the C-series of the Romnelet breed was significantly different from the other two and consequently this coefficient was excluded from the averages. In general these coefficients were higher than those obtained for the shearling weight-mature weight relationship (see Table 2) with the average of the three breeds ($r = +.76$) being significantly ($p < .01$) higher than the one obtained in the previous analysis ($r = +.67$).

TABLE 4.—AVERAGE SECOND-YEAR AND LIFETIME (3-5 YEARS) CLEAN WOOL PRODUCTION AND THE RESULTING COEFFICIENTS OF CORRELATION

Breed	Series	No. of fleeces	Average second-year fleece weight	Average total production (3-5 years)	Correlation coefficient
			(lb.)	(lb.)	
Canadian Corriedale	Z	7	5.06	15.13	+.79*
	B	36	5.06	14.65	+.62**
	C	16	5.25	14.96	+.81**
All series		59	5.11	14.77	+.69**
Rambouillet	Z	10	4.99	15.34	+.55
	B	44	5.29	15.92	+.81**
	C	18	5.55	15.68	+.82**
All series		72	5.31	15.78	+.80**
Romnelet	Z	18	5.69	16.64	+.89**
	B	28	5.62	15.90	+.77**
	C	24	5.82	16.86	+.52**
All series		70	5.71	16.66	+.82**[1]
Average of 3 breeds[1]					+.76**

* $p < 0.05$
** $p < 0.01$
[1] Romnelet C series not included (see text).

On this basis second fleece weight was a better indication of the inherent potentialities of the ewe than was the shearling weight, and is an indication that those wool characteristics which contribute to fleece weight were more fully established during the second year. This is confirmed by the fact that no appreciable increases occurred in subsequent annual production (see Table 1). The same situation also was reflected in the coefficient of determination, which increased from .44 to .59. It would appear that the variations in maximum fleece weights and lifetime production followed each other more closely and extraneous effects were less likely to disturb or weaken this relationship than when the shearling fleece weight was used for comparison. This was not because the relatively low coefficient in the Romnelet C-series was omitted as the inclusion of this value in the average would have decreased the value of "r" only by 0.021. It may be argued that, since second-year weight was more highly correlated with lifetime production than shearling weight, the former should provide the basis for the selection of replacement stock. However, Lerner (4) indicated that the additional genetic gains obtained from increasing the precision may be offset by a reduction of selection intensity.

The regression coefficients were $2.46 \pm .18$, $2.51 \pm .21$, and $3.02 \pm .26$, in the Canadian Corriedale, Rambouillet, and Romnelet, respectively. As would be expected they were somewhat lower than those obtained for the shearling weight-mature weight relationship.

Similarly, the correlation coefficients between shearling and second clean fleece weights were calculated for the ewes in each breed group. These values were found to be homogeneous except for the Z-series in the Romnelet breed and consequently were combined. The averages for breeds with the latter value excluded are shown in Table 5. Since the relationship between first- and second-year fleece weights was highly significant it further serves to emphasize the usefulness of first-year weight in selection of replacement sheep.

TABLE 5.—CORRELATION BETWEEN SHEARLING AND SECOND (MAXIMUM) FLEECE WEIGHTS

Breed	r
Canadian Corriedale	+.71**
Rambouillet	+.60**
Romnelet	+.54**

** $p<0.01$

Repeatability of Clean Fleece Weight

If the shearling clean fleece weight is to be accepted as an estimate of the wool production of the ewe during maturity, it is important to know whether this relationship is characteristic of the individual and therefore constant throughout its life, or if it is subject to changes relative to the ageing of the animal.

The persistence of the relationship was investigated in the following way. The shearling fleece weights of those ewes which had continuous records for at least 5 years were correlated successively with the second,

third, fourth, and fifth fleece weights, respectively. The correlations obtained for series and breed were tested for homogeneity employing the Z-test and the following average values calculated: the coefficients of correlation and determination, the regression coefficient together with its standard error, and the standard error of estimate (Table 6). It should be pointed out that the coefficients were homogeneous in all comparisons except that between the first and the fifth fleece weights. However, these coefficients were combined for comparison and are shown in parentheses.

The interesting feature shown in Table 6 is the gradual reduction in the degree of association between shearling and mature fleece weights as the ewes became older. The percentage of common elements in the variability was reduced from 44 per cent in the second year to about 23 per cent in the fifth year. Although the reduction in the value of the regression coefficients probably is no more than a reflection of the gradual change in the relationship of the fleece weights with progressing age, the estimates became more unreliable. This is evident from the increase of the standard errors of estimate up to the fourth year.

TABLE 6.—CORRELATION BETWEEN SHEARLING FLEECE WEIGHT AND WOOL PRODUCTION IN SUBSEQUENT YEARS (BREEDS AND SERIES COMBINED)

Fleece data correlated	r	d	$b_{xy} + \sigma b$	$\overline{sy.x}$
1st year with 2nd year	+.66	.44	.86±.06	.48
1st year with 3rd year	+.61	.37	.78±.07	.56
1st year with 4th year	+.56	.31	.75±.08	.66
1st year with 5th year*	(+.48)	(.23)	(.64±.08)	(.66)

* See text above

The repeatabilities, calculated on the basis of the adjusted clean fleece weights, were as follows:

Breed	Repeatability
Rambouillet	0.93
Romnelet	0.83
Canadian Corriedale	0.76

It is evident that the repeatability of clean fleece weight in the three breeds studied was relatively high. Similar information was not found on reviewing the literature for clean weights but for grease weights repeatabilities ranged from 0.5 to 0.6 (4,9). However, a higher value would be expected from the present data since a number of the environmental factors have been removed in obtaining clean weights. The repeatability of these weights for the Rambouillet was significantly higher ($p<.01$) than that for the Canadian Corriedale and Romnelet but no difference in the repeatability of production from the latter two breeds was found.

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THE RELATIONSHIP OF CLEAN FLEECE WEIGHT TO AGE IN THREE BREEDS OF RANGE SHEEP[1]

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ABSTRACT

A total of 1,457 clean fleece weights, representing 7 years of production and adjusted for certain environmental factors, were used in this study. The data were analysed to determine the relationship of clean fleece weight to age in the Rambouillet, Romnelet, and Canadian Corriedale breeds of range sheep maintained under Western Canadian conditions.

In general, maximum fleece weight was attained by the second year of production and was maintained until the end of the fourth year in all breeds. At that time a significant ($p < .01$) decline occurred which continued until the end of the seventh year. Among the Rambouillet and Romnelet ewes which were born and raised as singles, a small additional increase in average fleece weight occurred in the third year. Ewes born and raised as singles tended to produce more wool than twins but the differences were significant ($p < .01$) only in the Romnelet shearlings. The data suggest that in twins maximum production occurred at a slightly earlier age and that the subsequent decline began sooner than in singles.

INTRODUCTION

It is well known that the physiological changes which accompany maturing and ageing in sheep find their expression in wool production. In a previous paper (4) on the relationship of shearling clean fleece weight to mature production, it was noted that maximum fleece weight was attained by the second year of life and that this level of production remained relatively constant until the end of the fourth year. In the fifth year of production a significant decline had begun. Williams and Cunningham (6) observed that in certain English breeds and their crosses the third fleece was the heaviest. A similar observation was made by Spencer (5) for Rambouillets. On the other hand, Lush and Jones (2) found the second year of life to coincide with maximum wool production. However, in all these studies the age effect appeared to be confounded with year effect and this constituted a difficulty in establishing the exact relationship. In the Langhe sheep of Italy, Mason and Dassat (3) found no consistent trend in fleece weights. In one group of ewes there was a gradual but diminishing increase up to 8 years of age, while in a second group the second fleece weight was the heaviest. No correction was made for the year effect, although it was expected that this would have a negligible influence, because data representing several years were grouped together. Johannson and Berg (1) reported that, in the Oxford, Shropshire, and Cheviot breeds, maximum production was reached in the third year of life. However, this result should be treated with some caution as the second fleece weights represented only 9-10 months of growth. It appeared that, if fleeces representing a full year of growth were compared, the second year of production was the maximum. These workers further indicated that the

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[2]Deceased.

shape of the age-fleece-weight curves depended on the reproductive activity of the ewes. The age at first lambing seemed to be important in this respect. In ewes which lambed as shearlings, maximum wool production was shifted from the second to the third year.

In view of the variations reported by other workers in lifetime wool production, it was decided to analyse the data presented previously (4) on an adjusted clean fleece weight basis to determine the annual productivity and its relation to the sheep's age.

MATERIALS AND METHODS

A total of 1,457 clean fleece weights, representing 7 years of production, were analysed in this study. It was pointed out previously (4) that by using the clean fleece weights the effect of impurities was removed. In addition, all data were corrected for the lambing performance of the ewe by adjusting them to a single-pregnancy, single-lactation basis, and for variations from year to year due to the nutritional and climatic environment.

In determining the effect of age on clean fleece weight only those ewes which had records for at least the first 5 years were considered. In this way data for the same group of animals could be evaluated. Approximately 60 per cent of the experimental ewes produced fleeces in the sixth year and 30 per cent in the seventh. No selection for economic characters was practised after the first year of production and the only reasons for removing ewes from the study was because of broken mouths or defective udders. Analyses of variance indicated that there were no differences in the average weight of the fifth fleece between those ewes which ceased production in that year, those which ceased in the sixth, and those which ceased in the seventh. Consequently, it was assumed that the latter two groups of ewes were representative of those studied.

To study the effect of type of birth and rearing on wool production the data were separated into two groups. The first group included the ewes which were born and raised as singles or born as twins, but raised as singles, whereas those born and raised as twins made up the second group.

RESULTS AND DISCUSSION

The year averages for ewes born and raised as singles and as twins for each of the three breeds were calculated and plotted against age. The curves were fitted by hand and are shown in Figure 1.

In the Canadian Corriedale a significant ($p < .01$) increase in average clean fleece weight occurred in the second year of production when compared to the shearling weight. In that year maximum production was obtained. From the second to the fourth year production remained essentially the same but in the fifth year a significant decline ($p < .05$) occurred which continued in the sixth and seventh year ($p < .01$) of production. In the final year the average fleece weight in both singles and twins ($p < .01$) had declined below the shearling level of production. Although the average fleece weights of singles were consistently greater than those of twins, the differences were not statistically significant in any one year, which may be attributed at least in part to the relatively low numbers in the twin groups.

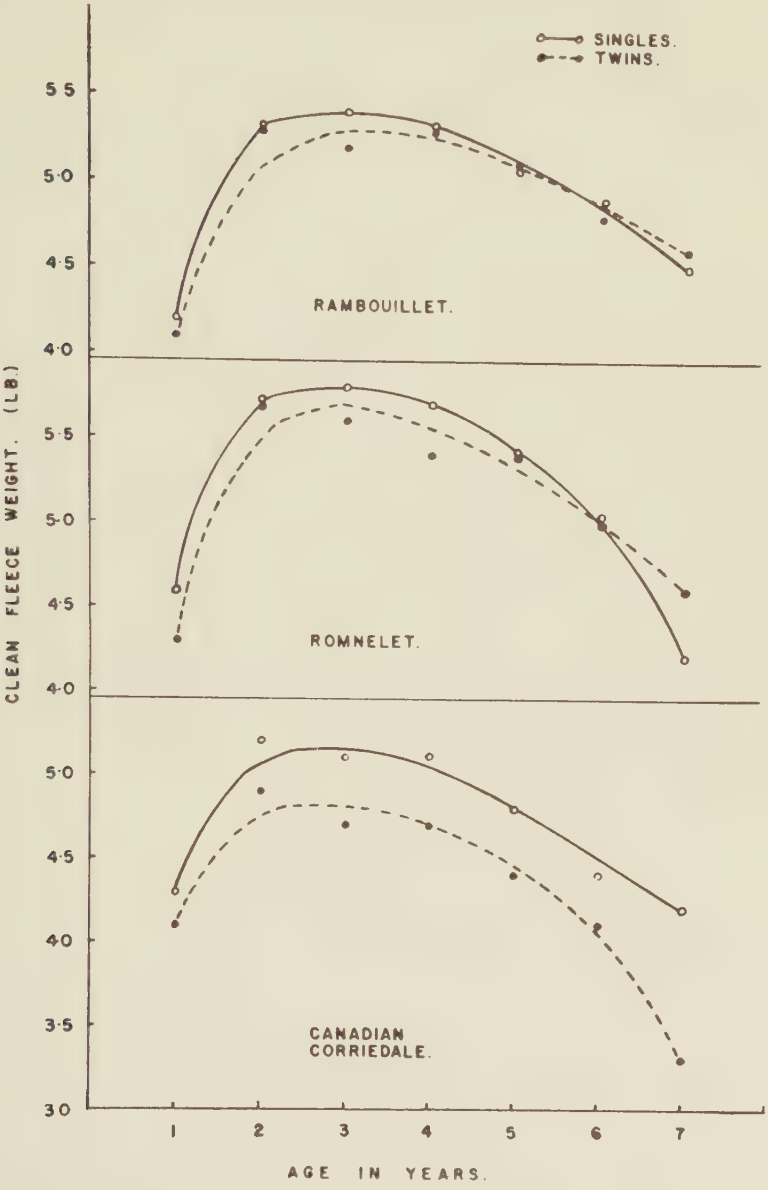

FIGURE 1. Clean wool production as a function of age in the Canadian Corriedale, Rambouillet, and Romnelet breeds.

Similarly, in the Rambouillet, clean fleece weights reached their maximum by the second year of production although in the singles a small additional increase occurred during the third year. The average fleece weights of the singles and twins combined were 5.31, 5.37, and 5.31 lb. for the second, third, and fourth years, respectively. After the fourth year there was a gradual decrease ($p < .01$) in fleece weight each year although production was maintained at a higher level than in the Corriedale and

even in the advanced years the average fleece weights did not drop below the shearling level. No significant difference was found in the average production between singles and twins.

In the Romnelet the relationship was similar to that prevailing in the previous two groups. Maximum production was attained by the second year of life, although a slight increase occurred in singles during the third year. The average fleece weights of the singles and twins combined were 5.71, 5.69, and 5.53 lb., respectively. Production began to decline in the fifth year and during the sixth year average weights were significantly ($p < .01$) below maximum production. From the sixth to the seventh year a further decline ($p < .01$) occurred. In the seventh year, the average weight from singles had declined significantly ($p < .01$) below the level of their shearling production while that of twins remained slightly above this level. The difference in clean weight between singles and twins was significant ($p < .01$) only in the first year of production.

The data have indicated that, in general, maximum production occurred in the second year of life. However, an observation of the graphs (see Figure 1) pertaining to single and twin fleece weights would suggest that in twins maximum production occurred at a slightly earlier age and that the decrease began somewhat sooner than in singles.

The shearling fleece weights from ewes which were born and raised as twins were 0.18, 0.10, and 0.37 lb. lower in the Canadian Corriedales, Rambouillets, and Romnelets, respectively, than from those born and raised as singles. This is in general agreement with the findings of Wright and Stevens (7) who reported a difference of 0.24 and 0.32 lb. in the hogget grease fleece weights (corresponding to approximately .012 to 0.16 lb. clean wool) in favour of the singles.

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REPLACEMENT OF SKIMMILK POWDER IN THE BABY PIG RATION BY A MIXTURE OF WHEY POWDER AND MEAT MEAL[1]

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ABSTRACT

The substitution of a mixture of meat meal and whey powder for the skimmilk powder in a dry early-weaning pig ration resulted in a decreased rate of gain and feed efficiency. These decreases were shown to be due, at least in part, to a lower digestibility of crude protein and total carbohydrate in meat meal and whey powder rations.

The addition of methionine did not improve rate of gain, feed efficiency or nutrient digestibility in any of the treatments studied. Thus, a methionine level of 0.65 per cent of the ration (2.5 per cent of the protein) appears to be adequate for pigs between 2 and 8 weeks of age.

Rate of gain of pigs fed rations containing 26 per cent protein was significantly greater than that of pigs fed 30 per cent protein rations; but, in terms of feed efficiency and nutrient digestibility, both levels of protein resulted in similar values.

The dry matter, gross energy, crude protein, ether extract and total carbohydrate of all rations were digested to a greater extent by 7- than by 3-week-old pigs.

A dry ration, formulated in this Department and designed for the feeding of early-weaned pigs, is now being used commercially in the Province of Quebec. Its use, however, is restricted to some extent by its high cost, mostly the result of a content of 37 per cent skimmilk powder.

Whey powder, a feed containing protein of similar origin, is much less costly, and might be considered a logical replacement for skimmilk powder. Although the protein of whey powder is as good, from the point of view of amino acid distribution, as the protein of skimmilk powder, the total protein content of the former is considerably lower than that of the latter. Therefore, in order to supplement for skimmilk powder and maintain the protein level of the ration, a combination of whey powder and one of the high protein feeds would be required. A 50-50 mixture of whey powder and meat meal would supply the same total concentration of protein as skimmilk powder, and on this basis might be substituted for it, pound for pound

Knowledge of the amino acid requirements of pigs under 25 lb. is still meagre. However, it can be shown that, in the early-weaning ration containing 37 per cent skimmilk powder, the amino acid least in excess of the U.S. National Research Council requirements of 25-70 lb. pigs is methionine. The substitution of a whey powder-meat meal mixture for skimmilk powder will lower the methionine level of the ration. Therefore, it is conceivable that the addition of methionine to the whey powder-meat meal substituted ration might be beneficial.

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It has been pointed out by Crampton and Ness (2) that a 30 per cent level of protein in this dry early-weaning pig ration is superior to a level of 26 per cent protein. However, the methionine content of the latter can be shown to be lower than that of the 30 per cent protein ration, leaving the possibility that the results were due not to an insufficiency of total protein, but to an insufficient methionine intake.

Therefore, the purpose of this experiment was to study modifications in the dry early-weaning pig ration by:

1) Substituting a mixture of whey powder and meat meal plus methionine for its total skimmilk powder content.

2) Fortifying the 26 per cent protein ration (2) with methionine to learn if the addition of methionine would make this ration equal in feeding value to that containing 30 per cent protein.

EXPERIMENTAL PROCEDURE

Animals

A total of 64 pigs, 32 farrowed in the fall of 1955 and 32 in the winter of 1956 in the Macdonald College swine herd, were weaned at approximately 14 days of age and placed on test in two replicates. Each replicate consisted of a 42-day feeding period. The pigs were housed in suitably heated pens in groups of 4, consisting of 2 males and 2 females. The animals were allotted at random as shown in Table 1.

Table 1.—Allotment of animals

Replicate	Supplementary methionine	Sex	Skimmilk powder		Whey powder + meat meal	
			Protein	Protein	Protein	Protein
			30%	26%	30%	26%
1	Absent	M	2 pigs	2 pigs	2 pigs	2 pigs
		F	2 pigs	2 pigs	2 pigs	2 pigs
	Present	M	2 pigs	2 pigs	2 pigs	2 pigs
		F	2 pigs	2 pigs	2 pigs	2 pigs
2	Absent	M	2 pigs	2 pigs	2 pigs	2 pigs
		F	2 pigs	2 pigs	2 pigs	2 pigs
	Present	M	2 pigs	2 pigs	2 pigs	2 pigs
		F	2 pigs	2 pigs	2 pigs	2 pigs

Rations

The composition of the rations fed in this experiment is given in Table 2. Since the methionine requirement of pigs of this age is not known, it should be noted that, in Ration 2, methionine was added so that this amino acid was present as 1 per cent of the ration. In Rations

TABLE 2.—COMPOSITION OF RATIONS

Ration ingredients	Ration number							
	1	2	3	4	5	6	7	8
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Wheat	10	10	22	22	10	10	22	22
Oat groats	15	15	20	20	15	15	20	20
Soybean oilmeal	10	10	10	10	10	10	10	10
Fishmeal	10	10	10	10	10	10	10	10
Brewers' yeast	5	5	5	5	5	5	5	5
Skimmilk powder	37	37	20	20	—	—	—	—
Meat meal	—	—	—	—	20	20	11	11
Whey powder	—	—	—	—	17	17	9	9
V.M.A.Supplement*	3	3	3	3	3	3	3	3
Cane molasses	10	10	10	10	10	10	10	10
Methionine	—	0.15	—	0.13	—	0.13	—	0.20
	%	%	%	%	%	%	%	%
% Protein in ration	30	30	26	26	30	30	26	26
% Methionine in ration	0.85	1.00	0.72	0.85	0.72	0.85	0.65	0.85

*V.M.A. Supplement
1 kgm. contains:

	gm.		gm.
Iodized salt	135	Riboflavin	0.13
Dynafos	645	Pyridoxine	0.13
Ferrous sulphate	38	Ca-pantothenate	0.26
Vit. B_{12} + Penicillin	70	Vit. A (250,000 i.u./gm.)	1.16
Chromic oxide	72.5	Vit. D_3(750,000 i.u./lb.)	38.50

4, 6 and 8, sufficient methionine was added to bring its level up to that calculated for Ration 1 (i.e., 0.85 per cent of the ration). Chromic oxide (Cr_2O_3) was incorporated in all rations to the extent of approximately 0.25 per cent of the dry matter content. All rations were given *ad libitum* to each group of four pigs. Suitable fonts provided water at all times.

Records and Excreta Collections

All pigs were weighed at the beginning of the test and weekly thereafter. Weekly feed consumption per pen of 4 pigs was recorded. During the second and sixth week of each replicate, representative feces samples were collected daily from each pen, dried at 100° C. for 24 hours, composited at the end of the period, and held for chemical analysis.

TABLE 3.—AVERAGE DAILY GAIN, DAILY FEED CONSUMPTION AND FEED EFFICIENCY DATA FOR THE EIGHT INDIVIDUAL TREATMENT GROUPS

Individual treatment comparisons	Average daily gain	Av. daily gain adjusted to equal initial weight	Average daily feed consumption	Av. feed efficiency (gm. feed/gm. gain)
	(gm.)	(gm.)	(gm.)	
1. Skimmilk powder – 30% Protein – 0.85% Methionine	318	323	748	2.3
2. Skimmilk powder – 30% Protein – 1.00% Methionine	346	349	681	2.0
3. Skimmilk powder – 26% Protein – 0.72% Methionine	366	365	802	2.2
4. Skimmilk powder – 26% Protein – 0.85% Methionine	350	335	832	2.5
5. Meat meal + Whey powder – 30% Protein – 0.72% Methionine	273	270	814	3.0
6. Meat meal + Whey powder – 30% Protein – 0.85% Methionine	298	293	776	2.7
7. Meat meal + Whey powder – 26% Protein – 0.65% Methionine	310	321	806	2.5
8. Meat meal + Whey powder – 26% Protein – 0.85% Methionine	314	317	816	2.6
Necessary differences (P=0.05)	34	29		

Chemical Analyses

All feed and feces samples were analysed for moisture, crude protein, ash and ether extract by A.O.A.C. methods. Total carbohydrate was determined "by difference" since the crude fibre content of all rations was negligible. Chromic oxide in all samples was determined by the method of Bolin *et al.* (1). The gross energy value of feed and feces samples was obtained, using a peroxide bomb calorimeter.

RESULTS AND DISCUSSION

The combined results of the two replicates for average daily gain, average daily gain adjusted statistically to equal initial weight, average daily feed consumption and feed efficiency (grams of feed per gram of gain) are given in Table 3 for the eight individual treatment groups. Regardless of criterion studied, the average values for the eight treatment groups were highly variable and, therefore, difficult to evaluate on an individual basis. Thus, it became obvious that interpretation of the data of this experiment would become more meaningful if comparisons were made on a main treatment basis, as in Table 4.

TABLE 4.—AVERAGE DAILY GAIN, DAILY FEED CONSUMPTION AND FEED EFFICIENCY DATA FOR MAIN TREATMENT COMPARISONS

Main treatment comparisons	Average daily gain	Average daily gain adjusted to equal initial wt.	Average daily feed consumption	Av. feed efficiency (gm. feed/ gm. gain)
	(gm)	(gm)	(gm)	
Skimmilk powder	345	343	766	2.2
Meat meal + Whey powder	299	300	803	2.7
Nec. diff. (P=0.05)	17	15		
No added Methionine	317	320	792	2.5
Added Methionine	327	324	776	2.4
Nec. diff. (P=0.05)	17	15		
30% Protein	309	309	755	2.4
26% Protein	335	335	814	2.4
Nec. diff. (P=0.05)	17	15		

The average apparent digestion coefficients of dry matter, gross energy, crude protein, ether extract and total carbohydrate, at 3 and at 7 weeks of age, are shown in Table 5 for the main treatment comparisons.

Skimmilk Powder vs. Meat Meal + Whey Powder

The attempt to replace all the skimmilk powder in the early-weaning pig ration by a mixture of meat meal and whey powder proved unsuccessful. This is shown by a statistically greater rate of gain by the pigs consuming the skimmilk powder-containing rations than by those consuming the

TABLE 5.—THE APPARENT DIGESTIBILITY OF VARIOUS RATION ENTITIES FOR THE MAIN TREATMENT COMPARISONS

Main treatment comparisons	Apparent Digestion Coefficients									
	Dry matter		Gross energy		Crude protein		Ether extract		Total carbohydrate	
	3 weeks	7 weeks	3 weeks	7 weeks	3 weeks	7 weeks	3 weeks	7 weeks	3 weeks	7 weeks
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Skimmilk powder	78	82	79	85	78	84	29	59	85	88
Meat meal + Whey powder	69	74	73	81	69	78	61	78	80	84
No added Methionine	74	78	76	83	74	81	44	67	82	86
Added Methionine	74	78	76	83	73	81	45	70	83	86
30% Protein	73	77	76	83	74	81	42	68	82	85
26% Protein	74	79	76	83	73	81	48	69	83	86

meat meal and whey powder containing rations (Table 4). This greater gain was accompanied by a lower intake of feed, the end result of which was a superior feed efficiency value for the skimmilk powder rations.

Upon examination of the digestibility data (Table 5), the reason for the failure of the meat meal and whey powder rations to support growth to the extent of the skimmilk powder rations becomes more apparent. The lower apparent digestibility of the crude protein and total carbohydrate in the former rations, at both 3 and 7 weeks of age, contributed to the lower digestibility of both dry matter and gross energy, thus decreasing the feeding value of the rations containing meat meal and whey powder. The fact that the ether extract of the meat meal and whey powder rations was digested to a greater extent was merely a reflection of a higher level of this entity in these rations (4.3 per cent versus 1.9 per cent in the skimmilk powder rations). However, because of the small amount of ether extract in either type of ration, relative to protein or carbohydrate, any difference in the apparent digestibility of the fat fraction did not contribute appreciably to the over-all usefulness of the rations.

Methionine Supplementation

In no individual case did the addition of methionine significantly increase rate of gain (Table 3), a fact which is borne out by the comparison between the "no added methionine" and "added methionine" rations (Table 4). The feed intake by pigs fed the latter rations was slightly lower, but not sufficient to result in any appreciable difference in feed efficiency values. Thus the addition of methionine did not enhance the supplementary value of the meat meal and whey powder substitutions, nor did it have any effect on the feeding value of the 26 per cent protein ration. It should also be noted that the addition of methionine had no effect on any of the digestion coefficients studied (Table 5).

30% vs. 26% Protein Rations

The comparison between the 30 per cent and 26 per cent protein rations provided unexpected findings. In the original research on dry early-weaning pig rations by Crampton and Ness (2), the 30 per cent level of protein was found to be superior to the 26 per cent level in promoting growth in pigs of this age. In this experiment, the average daily gain of pigs fed rations containing 26 per cent protein was actually superior to that of pigs fed rations containing 30 per cent protein (Table 4). Upon further observation, it was noted that the greater gain on the 26 per cent protein rations was the result of a greater intake of feed. In terms of units of feed per unit of gain, both levels of protein resulted in identical values. These similar feed efficiency values probably resulted from the fact that all entities of the 26 per cent protein rations were as well digested as those of the 30 per cent protein rations (Table 5).

The highly satisfactory results with the 26 per cent protein rations in these trials cannot be explained as being due to different sources of protein or to an effect of methionine. The relationship between treatments 1 and 3 in this test (Table 3), treatments identical to the rations used in the original comparisons of Crampton and Ness, was almost identical to the over-all results of 30 versus 26 per cent protein rations. Reasons for these conflicting results are not apparent.

In a study of the digestibility of ration nutrients by 3- vs. 7-week-old pigs by Lloyd *et al.* (4), it was found that the average apparent digestibility of the dry matter, gross energy, crude protein and ether extract of a dry early-weaning pig ration was higher for 7- than for 3-week-old pigs. The greatest difference occurred in the ether extract fraction. These findings are confirmed in their entirety in the present study. However, in our original work, it was stated that age of pig had no significant effect on carbohydrate digestibility. This is not borne out by the results reported here, since in all comparisons total carbohydrate was also digested to a greater extent by the older pigs.

Lewis *et al.* (3) have stated that the baby pig lacks fully developed proteolytic and amylolytic enzyme systems, and that the protein and carbohydrate of choice for pigs, at least prior to 5 weeks of age, are casein and lactose respectively. The superior results observed in this study with skimmilk powder-supplemented rations tend to confirm the Iowa findings.

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NUTRIENT REQUIREMENTS FOR CANADIAN YORKSHIRE SWINE.

II. THE EFFECTS OF BARLEY AND OAT FINISHING RATIONS ON RATE OF GAIN, FEED UTILIZATION AND CARCASS QUALITY OF PIGS MARKETED AT 185 AND 200 POUNDS LIVEWEIGHT

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ABSTRACT

Four stations co-operated in a statistically analysed feeding trial to compare barley and oats in self-fed finishing rations. Pigs fed barley gained 0.25 lb. more per day, consumed more TDN and calories daily, had higher dressing percentages, and received lower commercial grades for carcass quality. They had more back fat but Advanced Registry (AR) scores were not significantly different.

There was no improvement in commercial grades or AR scores when pigs were slaughtered at 185 instead of 200 lb. liveweight, although lighter pigs had less back fat. Significant differences between stations demonstrate importance of considering genetic and environmental influences when interpreting results of nutrition studies.

INTRODUCTION

Canadian Yorkshire pigs, fed as recommended in "*Nutrient Requirements for Swine*" (11), produced inferior, over-finished bacon-type carcasses (5). The fault appeared to be in rations fed to pigs weighing 110 to 200 lb.

Over-finish, within the desired market weight range, is recognized as the most common factor resulting in down-grading of market pigs in Canada. It has been demonstrated that carcass quality can be markedly influenced by plane of nutrition or energy intake, especially during the finishing period (7, 8, 10). It will be noted that the above-mentioned "*Requirements*" (11) involve the use of rations, for all classes of swine, containing 75 per cent T.D.N., a level of energy difficult to obtain without extensive use of wheat or corn. It is also a level now known (5) to be unnecessary for 'normal' gains and undesirable in finishing rations from the standpoint of maximum lean-to-fat ratios in the carcass.

The deposition of fat is positively correlated with liveweights and carcass weights of pigs, as was indicated by Fredeen (9) and others cited by him. Carcasses weighing between 145 and 165 lb. had 0.03 to 0.07 inches more shoulder-, back- and loin-fat thickness for each 5-lb. increase in carcass weight. Thus, it is apparent that market weight, independent of carcass length, is closely related to the general problem of over-finish.

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This report presents the results of an experiment to determine the effects on performance and carcass quality of: (a) marketing pigs at 185 versus 200 lb. liveweight, and (b) feeding oats versus barley as the grain component of the finishing rations for self-fed swine.

MATERIALS AND METHODS

Scope and Organization

This study was undertaken co-operatively by several institutions across Canada. The Universities of Alberta and Manitoba, Macdonald College (McGill University) and the Dominion Experimental Farm at Nappan, Nova Scotia, conducted swine-feeding trials and secured the desired carcass data in co-operation with the Marketing and Production Services, Canada Department of Agriculture. The Dominion Experimental Farm at Lethbridge, Alberta, subjected all rations to digestibility, nitrogen balance and energy balance tests. The formulation of all rations and co-ordination of the project were undertaken at the University of Saskatchewan.

The four stations, designated Alberta, Manitoba, Quebec, and Nova Scotia, conducted feeding trials with two replicate lots of 16 pigs each.

Between initial weights averaging 41.5 lb. and weights of 110 ± 5 lb. all pigs were fed a barley grower ration. Following this, half the pigs were allotted to a barley finishing ration and half to an oats finishing ration. Half of the pigs fed each finishing ration were slaughtered at liveweight of 180 to 185 lb. and the other half at weights of 200 to 205 lb. Barrows and gilts were equally represented and the tests were run in two consecutive replicates, except at Quebec where the replicates were conducted concurrently.

The pigs were weighed every 14 days and more frequently if necessary near ration change-over times or near marketing. Group feeding with four pigs per pen was practised at all stations except Quebec, which employed individual feeding.

Table 1.—Ration formulas for growing and finishing period

Ingredients	Ration		
	Grower	Barley finisher	Oat finisher
Barley, ground, lb.	85.85	93.50	—
Oats, ground, lb.	—	—	95.67
Soybean oilmeal, lb.	7.80	2.75	1.46
Meat meal, lb.	5.20	1.85	.97
Aurofac*, lb.	.25	—	—
Salt, lb.	.50	.50	.50
Limestone, lb.	.20	1.00	1.00
Fish oil (300D, 1500A), lb.	.20	—	—
Fish oil (150D, 1000A), lb.	—	.40	.40

* To supply 10 gm. aureomycin/ton of feed.

Rations

The grain and protein supplements were purchased in sufficient quantity to complete the study and were held in storage at Saskatoon, Saskatchewan, until needed. The barley contained 11.4 per cent crude protein and was graded No. 1 Feed. The oats contained 12.4 per cent protein and were graded No. 1 Feed. The grain was ground immediately prior to mixing.

The growing rations were designed to contain 16 per cent crude protein and 10 gm. aureomycin (chlortetracycline) per ton of feed. Calcium, phosphorus and vitamin A were added in amounts sufficient to meet the 1953 Requirements (11) for pigs weighing 50 lb.

The two finishing rations were formulated to provide 13 per cent crude protein and to meet the Requirements otherwise for 150 lb. pigs. The formulas are shown in Table I.

Chemical Analysis and Digestion and Metabolism Studies

Samples of the three rations were analysed for crude protein, crude fibre, ash, ether extract, gross energy, calcium (Ca) and phosphorus (P). Energy was determined with an oxygen bomb calorimeter (1). The method of Snell and Snell (12) was employed for phosphorus. The other components were analysed according to A.O.A.C. methods (3).

The grower ration was fed to each of four barrows weighing about 70 lb. initially and confined to metabolism cages patterned after those of Bell (4) in order to obtain digestibility, nitrogen and energy balance data. Each finisher ration was similarly tested with separate groups of four barrows weighing about 105 lb. initially. Collection periods were of 10 days' duration, preceded by 5-day preliminary periods. A ferric oxide (Fe_2O_3) feces colour marker was added to the feed at the beginning and end of each collection period to facilitate fecal collections. Urine was collected separately and analysed for nitrogen and energy.

Carcass Quality Measurements

Measurements taken according to Advanced Registry (A.R.) (2) standards included dressing percentage, carcass weight, length, fat depths at shoulder, back and loin, area of loin muscle and percentage shoulder.

The carcasses were also graded commercially by local inspectors at marketing-points near each of the four stations. Grade A pigs have carcasses ranging in weight from 140 to 170 lb., 29 inches minimum length, 2 inches maximum shoulder fat, and 1.5 inches maximum loin fat. Grade B_1 carcasses range in weight from 135 to 175 lb.; they may carry more back fat and must be within the length range of 28 to 29 inches. Grade C pigs are penalized mainly for overfinish, together with shortness and poor type or balance.

RESULTS AND DISCUSSION

Composition and Utilization of the Rations

The chemical composition and digestibility data for the three rations are shown in Table 2. All rations analysed higher in protein than was intended. The effects of this situation on other results from this experiment cannot be appraised from information at present available but it is conceivable that the ratio of protein to energy in the ration would be related to fat-to-lean ratios in the carcass.

TABLE 2.—COMPOSITION, DIGESTIBILITY, ENERGY AND NITROGEN UTILIZATION DATA FOR THE RATIONS USED IN FEEDING EXPERIMENTS

Item	Ration		
	Grower	Barley finisher	Oat finisher
	Percentage composition, air-dry basis		
Water	10.5	8.3	7.4
Crude protein (N × 6.25)	16.6	14.0	14.3
Crude fibre	4.7	4.1	9.5
Ash	5.1	7.6	6.9
Ether extract	3.3	2.5	4.2
Nitrogen-free extract	59.8	63.5	57.7
Calcium	0.34	0.42	0.43
Phosphorus	0.33	0.47	0.37
	Digestibility coefficients, %; energy and protein values		
Digestibility of dry matter	81.1	83.0	71.9
Digestibility of protein	79.0	77.9	81.2
Digestibility of fibre	28.9	22.6	19.4
Digestibility of ether extract	71.0	64.8	78.9
Digestibility of N.-F.E.	89.0	90.4	79.8
T.D.N., %	72.9	72.8	67.1
D.C.P., %	13.1	10.9	11.6
Gross energy, Cal./gm.	4.06	3.89	4.11
Digestibility of energy, %	81.3	81.7	72.1
Digestible energy, Cal./gm.	3.30	3.18	2.96
Metabolizable energy, Cal./gm.	3.18	3.07	2.86
Digestible Cal./gm. T.D.N.	4.53	4.37	4.41
	Nitrogen balance data		
Av. test weight of pig, lb.	78.5	112.0	109.5
Apparent biological value, %	42.3	38.0	40.4

The barley grower and finisher rations had 73 per cent T.D.N. and the oats finisher contained 67 per cent, both below the standard value of 75 per cent. Associated with the lower T.D.N. content of the oats finisher relative to the barley, were higher crude fibre content and lower digestibility coefficients for dry matter, crude fibre, nitrogen-free extract and gross energy.

Evaluations according to digestible energy tended to parallel the T.D.N. values as indicated by the finding that Cal./gm. T.D.N. varied from 4.4 to 4.5 but there were some noteworthy deviations from this general relationship. Of special interest is the fact that, whereas the T.D.N. values for the barley grower and finisher rations were equal, the digestible energy values were 3.30 and 3.19 Cal./gm., a 3.6. per cent reduction. Corresponding differences existed in metabolizable energy values.

Calcium contents were appreciably below the standards of 0.65 and 0.55 per cent for both feeding periods and phosphorus was lower during the growing period than the standard value of 0.45 per cent.

TABLE 3.—GROWTH AND FEED CONSUMPTION DURING THE GROWING PERIOD

Comparison	Initial weights (av.)	Initial ages	Daily gains	Daily feed intakes	Feed per lb. gain	T.D.N. per lb. gain	Metab. energy per lb. gain	Digest. energy per lb. gain
	lb.	days	lb.	lb.	lb.	lb.	therms	therms
Between stations								
Alberta	40	64	1.35	4.14	3.07	2.24	4.43	4.59
Manitoba	41	63	1.31	3.98	3.04	2.22	4.39	4.56
Quebec	46	65	1.43	4.32	3.02	2.20	4.36	4.52
Nova Scotia	39	59	1.44	4.32	3.00	2.19	4.34	4.51
Necessary difference (P=.05)			*0.09*	*0.16*				
Between finishing ration allotments (110 lb. to market weight @ 185 or 200 lb. lwt.)								
Barley finisher	41	63	1.37	4.24	3.09	2.26	4.42	4.63
Oat finisher	41	63	1.38	4.15	3.01	2.19	4.34	4.50
Necessary difference (P=.05)			*0.06*	*0.11*				
Between market wt. allotments								
185 lb. market weight	42	63	1.38	4.23	3.07	2.23	4.43	4.59
200 lb. market weight	41	63	1.36	4.15	3.05	2.20	4.41	4.57
Necessary difference (P=.05)			*0.06*	*0.11*				
Between sexes (for Quebec pigs only)								
Females	44	64	1.42	4.25	2.99	2.18	4.31	4.47
Males	47	66	1.44	4.41	3.06	2.23	4.41	4.57
Necessary difference (P=.05)			*0.08*	*0.27*				

Growth and Feed Utilization during the Growing Period (40 to 110 lb. Liveweight)

The results obtained during this period are presented in Table 3. Pigs in Quebec and Nova Scotia gained significantly faster than those in Manitoba. While it is probable that some of the apparent advantage shown by the Quebec pigs was due to their higher initial weights, it appears that local environmental and genetic factors were also involved. Males gained faster than females in all comparisons. Otherwise there were no differences in growth rates, which implies that the allotment of animals to finishing rations was unbiased.

Feed consumption and utilization appear to be correlated with rates of gain. Manitoba pigs ate less feed per day than pigs at any other station and Alberta pigs ate less than Quebec and Nova Scotia pigs. In the Quebec test, where individual feeding was practised, it was found that males ate significantly more than females and were more efficient in utilizing their feed.

Nitrogen balance studies of the grower ration revealed a biological value of 42 per cent. However, with the level of protein fed being 16.6 per cent and the average test weight of the pigs being 78 lb., it is probable that the low biological value was due to the protein level being too high in relation to the needs of the pigs. The pigs gained well (1 lb. per day) during the nitrogen balance tests as well as in the feeding trials elsewhere, so there is little reason to suspect that quality of protein was as low as indicated by the biological value obtained.

Growth and Feed Utilization during the Finishing Period (110 to 185 or 200 lb. Liveweight)

Variance analysis of the average daily gains made during the finishing period are shown in Table 4 and revealed differences between stations and between the two finishing rations. Departing somewhat from the performance during the growing period, the Manitoba and Nova Scotia pigs gained faster than Alberta and Quebec pigs.

Pigs fed barley gained approximately 0.25 lb. per day more than those fed oats. There were no other differences in growth rates relating to previous performance, sexes or market weights.

Examination of the average daily feed intakes showed that Nova Scotia pigs consumed more daily feed than pigs at any other station, the difference being highly significant. In general there was no difference between feed intakes on barley and oat finishing rations but there was a station and ration interaction effect. Alberta and Manitoba pigs consumed more barley than oats, whereas the reverse was true for the other two stations. These differences in feed consumption did not always parallel the differences observed in rates of gain because of the difference in T.D.N. or digestible energy in oat and barley rations and, having only group data for feed intakes, it was impossible to study the correlation between the two factors in more detail.

A significant difference was found between replicates with respect to feed intakes. In all cases except Quebec, where the replicates were run concurrently, the pigs in the first replicate (spring and summer) consumed the most feed.

TABLE 4.—EFFECTS OF FINISHING RATION AND STATION ON RATE OF GAIN AND FEED UTILIZATION OF YORKSHIRE PIGS BETWEEN 110 AND 185 OR 200 LB.

Comparisons	Daily gain	Daily consumption per pig of			
		Feed	T.D.N.	Dig. energy	Metab. energy
	lb.	lb.	lb.	therms	therms
Between stations					
Alberta	1.46	6.28	4.40	8.77	8.46
Manitoba	1.61	6.33	4.45	8.85	8.55
Quebec	1.40	6.24	4.35	8.68	8.38
Nova Scotia	1.69	7.01	4.90	9.77	9.43
Necessary difference (P =.05)	*.10*	*.23*	*.23*	*.40*	*.40*
Between market weights					
185 lb.	1.52	6.54	4.58	8.92	8.61
200 lb.	1.56	6.39	4.47	9.12	8.80
Necessary difference (P =.05)	*.07*	*.16*	*.16*	*.28*	*.28*
Between finishing rations					
Barley	1.67	6.53	4.75	9.43	9.11
Oats	1.41	6.40	4.29	8.60	8.30
Necessary difference (P =.05)	*.07*	*.16*	*.16*	*.28*	*.28*
Station and weight interaction effects					
Alberta 185 lb.	1.45	6.20	4.34	8.65	8.34
200 lb.	1.46	6.37	4.46	8.89	8.58
Manitoba 185 lb.	1.53	6.28	4.40	8.76	8.46
200 lb.	1.69	6.40	4.50	8.95	8.64
Quebec 185 lb.	1.43	6.16	4.31	8.59	8.29
200 lb.	1.38	6.31	4.40	8.78	8.34
N.S. 185 lb.	1.68	6.94	4.85	9.86	9.33
200 lb.	1.69	7.08	4.95	9.67	9.52
Necessary difference (P =.05)	*0.14*	*.32*	*.32*	*.57*	*.57*
Station and ration interaction effects					
Alberta Barley	1.58	6.49	4.72	9.37	9.04
Oats	1.34	6.08	4.08	8.16	7.88
Manitoba Barley	1.75	6.76	4.92	9.76	9.43
Oats	1.48	5.91	3.97	7.95	7.67
Quebec Barley	1.57	6.05	4.41	8.74	8.44
Oats	1.24	6.42	4.31	8.62	8.32
N.S. Barley	1.79	6.82	4.97	9.85	9.51
Oats	1.58	7.20	4.84	9.68	9.34
Necessary difference (P =.05)	*0.14*	*.32*	*.32*	*.57*	*.57*
Weight and finishing ration interaction effects					
185 lb. Barley	1.67	6.48	4.71	9.35	9.03
lb. Oats	1.38	6.31	4.23	8.48	8.18
200 lb. Barley	1.67	6.59	4.79	9.51	9.18
lb. Oats	1.44	6.50	4.36	8.73	8.42
Necessary difference (P =.05)	*.10*	*.23*	*.23*	*.40*	*.40*

Average daily intakes of T.D.N. showed larger intakes by pigs fed barley finishing rations. This effect proved independent of market weights but varied between stations, in that Alberta and Manitoba pigs ate more barley T.D.N. whereas pigs at the other two stations obtained similar daily T.D.N intakes from the two rations. The reasons for these behaviour differences are not apparent from these data but they would be of definite interest in relation to attempts to influence energy intakes by self-fed pigs. The correlation between T.D.N. intakes and daily gains was significant on the basis of group comparisons ($r=0.65$; 10 D.F.).

Analysis of the average daily digestible energy intakes revealed effects generally similar to those in the T.D.N. studies, although two comparisons in the station × ration × market weight interaction reached statistical significance. The Manitoba barley-fed pigs, marketed at 200 lb., consumed more digestible energy per unit gain than did those marketed at 185 lb. In Quebec, with pigs marketed at 185 lb., those fed barley obtained more digestible energy than those fed oats.

Metabolizable energy data also corresponded closely to the results in terms of T.D.N.

TABLE 5.—EFFECTS OF WEIGHT WHEN MARKETED, TYPE OF FINISHING RATION, SEX AND STATION ON CARCASS QUALITY OF YORKSHIRE PIGS

Comparisons	A.R. score	Dressing percentage	Carcass length	Shoulder	Loin area	Commercial grade	Max. shoulder fat	Loin fat
	%	%	in.	%	sq. in.	% A'S	in.	in.
Between stations								
Alberta	70.44	78.86	30.07	28.26	3.80	66	1.92	1.37
Manitoba	73.81	78.82	30.50	26.74	3.82	47	1.89	1.51
Quebec	—	75.06	29.79	—	3.85	28	1.87	1.54
Nova Scotia	69.37	76.61	30.28	26.27	3.67	34	1.95	1.55
Necessary difference (P =.05)	*7.00*	*.91*	*.33*	*.49*	*.20*		*.07*	*.07*
Between market weights								
185 lb.	71.52	77.12	29.82	27.47	3.71	42	1.87	1.44
200 lb.	70.88	77.56	30.53	26.71	3.86	45	1.95	1.54
Necessary difference (P =.05)	*5.72*	*.64*	*.23*	*.40*	*.14*		*.05*	*.05*
Between finishing rations								
Barley	68.76	77.98	30.10	26.96	3.80	34	1.94	1.52
Oats	73.63	76.69	30.24	27.20	3.77	53	1.88	1.46
Necessary difference (P =.05)	*5.72*	*.64*	*.23*	*.40*	*.14*		*.05*	*.05*
Between sexes								
Females	80.04	77.00	30.34	27.05	4.05	59	1.85	1.44
Males	62.37	77.67	30.00	27.11	3.52	28	1.97	1.54
Necessary difference (P =.05)	*5.72*	*.64*	*.23*	*.40*	*.14*		*.05*	*.05*
Station and weight interaction effects								
Alberta 200 lb.	71.00	79.18	30.38	27.99	3.91	56		
185 lb.	69.87	78.54	29.77	28.52	3.70	75		
Manitoba 200 lb.	74.56	78.49	30.83	26.23	3.80	50		
185 lb.	73.06	79.14	30.17	27.25	3.85	44		
Quebec 200 lb.	—	75.77	30.22	—	3.96	31		
185 lb.	—	74.34	29.36	—	3.73	25		
N.S. 200 lb.	69.00	76.78	30.63	25.90	3.78	44		
185 lb.	69.75	76.44	29.93	26.64	3.56	25		
Necessary difference (P =.05)	*9.90*	*1.29*	*.46*	*.70*	*.29*			
Station and ration interaction effects								
Alberta Barley	68.44	79.59	30.03	28.02	3.81	56		
Oats	72.44	78.14	30.12	28.49	3.80	75		
Manitoba Barley	72.31	79.77	30.53	26.75	3.85	37		
Oats	75.31	77.86	30.47	26.73	3.79	56		
Quebec Barley	—	75.30	29.74	—	3.82	19		
Oats	—	74.82	29.84	—	3.87	37		
N.S. Barley	65.56	77.28	30.06	26.14	3.73	25		
Oats	73.19	75.94	30.51	26.14	3.61	44		
Necessary difference (P =.05)	*9.90*	*1.29*	*.46*	*.70*	*.29*			
Weight and ration interaction effects								
Barley 200 lb.			69.03	78.41	30.37	26.48	3.91	31
185 lb.			68.49	77.56	29.81	27.45	3.70	37
Oats 200 lb.			73.99	76.70	30.66	26.92	3.82	59
185 lb.			73.28	76.68	29.80	27.48	3.72	47
Necessary difference (P =.05)			*7.00*	*.91*	*.33*	*.49*	*.20*	
Weight and sex interaction effects								
Female 200 lb.			81.15	77.13	30.65	26.73	4.10	66
185 lb.			78.90	76.87	30.02	27.38	4.00	53
Male 200 lb.			61.87	77.98	30.38	26.68	3.63	25
185 lb.			62.86	77.36	29.60	27.55	3.41	31
Necessary difference (P =.05)			*7.00*	*.91*	*.33*	*.49*	*.20*	
Ration and sex interaction effects								
Female Barley			76.61	77.69	30.24	26.92	4.05	50
Oats			83.44	76.32	30.43	27.18	4.05	69
Male Barley			60.91	78.28	29.94	27.00	3.55	19
Oats			63.82	77.06	30.03	27.22	3.49	38
Necessary difference (P =.05)			*7.00*	*.91*	*.33*	*.49*	*.20*	

The good agreement obtained between these three measures of feed energy (T.D.N., digestible energy and metabolizable energy) favours the adoption of calorimetry as a routine feed analysis, particularly in view of its ease of determination.

Effects on Carcass Quality

It is apparent (Table 5) from the differences in the percentages of grade A pigs marketed that some important effects were obtained. A

statistical analysis of the commercial grades was carried out after assigning numerical ratings to the grades: 3 points for A, 2 points for B, and 1 point for grade C. On this basis there was no advantage in marketing pigs at 185 lb. as opposed to 200 lb. liveweight but there was definite improvement noted in the case of pigs fed oats rations as compared to barley rations. The typical superiority of females over males was also noted. In this regard it should be noted that 9 female and 2 male pigs (from Quebec and Nova Scotia) failed to qualify for grade A carcasses on account of yielding carcasses below the 140-lb. minimum weight. These all belonged to the group marketed at 185 lb. liveweight and pigs from these two stations had significantly lower dressing percentages than occurred in Alberta and Manitoba. It is probable that most of these pigs would have graded A had they been marketed a few pounds heavier, in which case the margin in favour of oats finishing rations would have been larger and the early-marketed pigs may have excelled those marketed at 200 lb. liveweight.

In contrast to some extent with commercial grades, the A.R. scores revealed no significant differences between any comparisons except sexes. The difference between sexes agrees with the findings of Fredeen (9) although the advantage in favour of females was more pronounced. It was observed that the average scores obtained were consistently below the minimum of 75 required to qualify on A.R. test; nevertheless the general carcass rating was undoubtedly superior to that obtained in the previous study (5).

It is probable that much of the difference between the two systems of grading results from the fact that under A.R. testing the various carcass aspects are rated according to a graduated scale, whereas with commercial grading failure to meet the standards in any one aspect automatically relegates the carcass to a lower grade. Thus, unlike the A.R. system, grading makes little allowance for certain superior traits compensating for weaknesses elsewhere in the carcass.

In this study, and involving only those pigs yielding carcasses weighing 140 lb. or more, the average A.R. score for 48 grade A pigs was 82 (58 to 98). Grade B_1 pigs (44) averaged 60 by A.R. score (range 20 to 77) and two grade C pigs averaged 54. Only 6 per cent of the pigs failed to have the minimum 29 inches of carcass length required to qualify for grade A, whereas 73 per cent of them failed to meet the minimum 30.5 or 31.0 inches required for their respective weight classes according to the A.R. system. This can be interpreted to mean that, as a rule, pigs which failed to grade A were disqualified on account of degree of finish. It seems that commercial grades perhaps were better indices of carcass quality than were total A.R. scores because the latter allows specific carcass weaknesses to be obscured by high-scoring components of the carcass.

A study of the dressing percentages showed a highly significant difference in favour of the barley-fed pigs, the actual difference being 1.3 percentage units. There was no correlation between dressing percentage and shoulder fat thickness in this experiment ($r = 0.04$, 120 D.F.), so it probably can be assumed that the higher dressing percentages in barley-fed pigs were not due primarily to a greater degree of finish. It is possible that

this difference was related to the lower density of the oats ration and in turn to an increase in digestive capacity, a phenomenon observed previously by Bohman *et al.* (6).

Significant station differences also occurred, with Alberta and Manitoba pigs dressing 78.9 and 78.8 per cent respectively; Nova Scotia 76.6 per cent; and Quebec 75.1 per cent. The extent to which station differences may be related to gastro-intestinal fill at time of slaughter cannot be determined, but this may offer a partial explanation of these findings.

Carcass length is an important characteristic under both A.R. and grading systems; however, there was no difference in length found between pigs fed oats or barley finishing rations. As was expected, pigs differed according to market weights and sexes. There were highly significant differences between stations. Percentage shoulder on the carcass displayed the same effects as carcass lengths.

Loin area is also an important index of the development of desirable meat regions but rations were similar in their effects on this measurement. The only differences observed pertained to market weights and to sexes.

As mentioned above, it appears that failure to obtain top grades was most often due to degree of finish. Pigs fed barley finishing rations had consistently more fat covering (shoulder and loin fat) than did those fed oats ($P = < .01$). There was likewise the most back fat on pigs marketed at 200 lb.

Associated with the differences noted in daily gains is the observation that barley-fed pigs attained 200 lb. liveweight at 167 days of age and the oat-fed pigs required 176 days. The corresponding ages for the 185-lb. marketing weights were 158 and 167 days. It is thus obvious that the growth rates for all pigs represented rapid development and this may explain the general inability in this experiment to detect more changes in carcass characteristics as were found by McMeekan (10) whose animals displayed a greater range of ages and growth rates.

It can be concluded that the use of oats as opposed to barley, as the grain in the finishing ration, resulted in improvement of swine carcasses. This appears to be related to the decreased daily energy intakes and in turn to a reduction in the amount of fat covering on the carcass. Marketing at 185 lb. liveweight also resulted in reduced back fat production but did not consistently improve carcass quality, often because the carcass lacked sufficient length or weight to qualify for high grades or scores.

Differences between stations in rates of gain, feed intakes and carcass characteristics as found in this experiment indicate that inherent differences between strains of swine and differences in environment should be taken into consideration in relation to any general feeding recommendations that may be developed for finishing rations.

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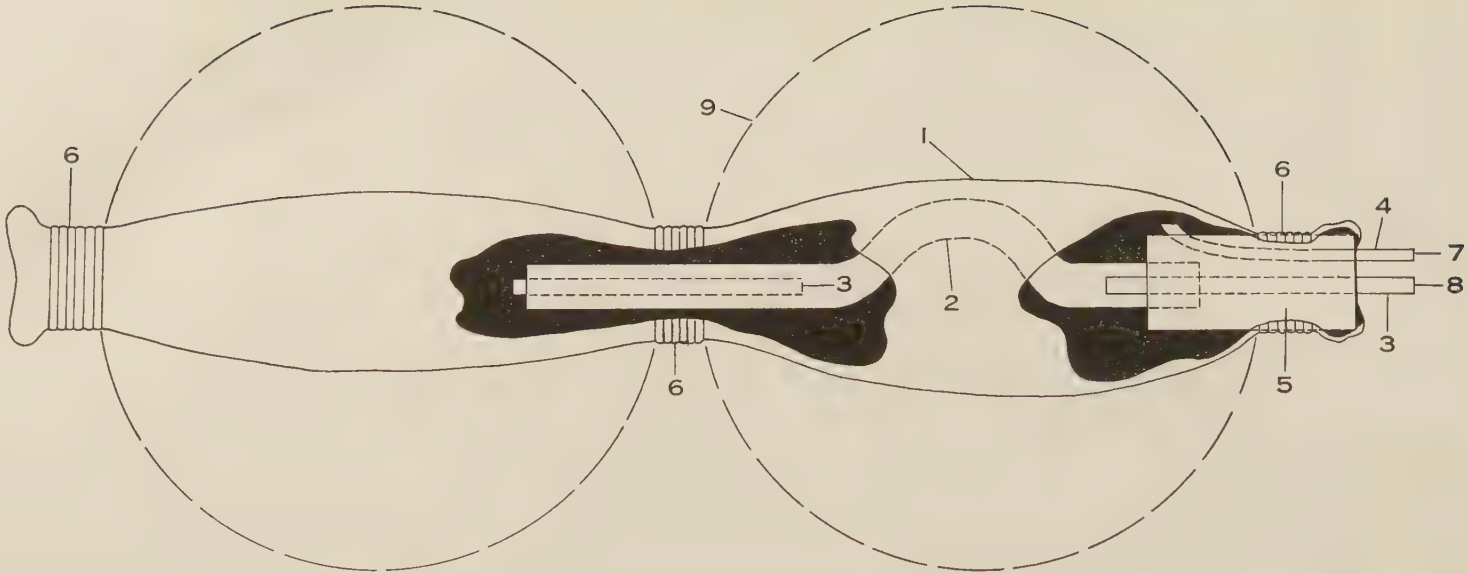

FIGURE 1. Diagram of the inflatable reticulo-omasal plug. The labelled parts are described as follows with dimensions of the tubing given in the order of length, internal diameter, and wall thickness.

1. Gooch rubber tubing, double ply: 10″, 3″, $\frac{1}{32}$″.
2. Rubber tubing: $5\frac{1}{2}$″, $\frac{7}{32}$″, $\frac{3}{32}$″. A small loop is left in the first chamber to allow for any stretching of the Gooch tubing.
3. Polyethylene tubing: $3\frac{1}{2}$″, $\frac{5}{32}$″, $\frac{1}{16}$″.
4. Polyethylene tubing: $3\frac{1}{4}$″, $\frac{1}{8}$″, $\frac{1}{16}$″.
5. Rubber tubing: 2″, $\frac{3}{8}$″, $\frac{1}{8}$″. A small hole $\frac{1}{8}$″ in diameter is bored in the side for tube 4.
6. The Gooch tubing is sealed with rubber cement and then tightly bound with heavy nylon or water-proof cord.
7, 8. Rubber inflation tubes with screw clamps are attached here: 2′, $\frac{1}{8}$″, $\frac{1}{16}$″, and 2′, $\frac{3}{16}$″, $\frac{3}{32}$″, respectively.
9. Approximate outline of plug when each chamber is inflated with 2 litres of air. (A small electric pump may be used in line with two large suction flasks to displace 2 litres of air with water).

INFLATABLE PLUG FOR RETICULO-OMASAL ORIFICE AND EQUIPMENT FOR SALIVA COLLECTION FROM FISTULATED STEERS[1]

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Methods described for "isolating" the rumen of sheep entail extensive surgery and the death of one animal for each experiment (1). This is unnecessary with fistulated steers. As this report shows, it is possible to "isolate" a rumen repeatedly without anaesthesia or injury by using removable plugs in the reticulo-omasal orifice and oesophagus.

The inflatable plug for the recticulo-omasal orifice (Figure 1) is made from double-ply Gooch rubber tubing. This is divided into two chambers by sealing it at the centre and at both ends with rubber cement and nylon cord. Just prior to sealing, the chambers are supplied with separate inflation tubes. One chamber is inflated in the omasum and the other in the reticulum.

The plug is tested by placing in the rumen 200 gm. of chromic oxide suspended in water with sodium bentonite. After 6 hours, the ingesta are removed, the rumen is rinsed repeatedly with warm water and the contents replaced with chromic oxide-free ingesta taken from another fistulated steer. Any chromic oxide leaking past the plug is later recovered in the feces. Tests using this procedure have shown that the plug is 99.7 to 100 per cent effective.

Saliva is collected with an inflatable rubber catheter (Figure 2) similar to that described previously (2). A polyethylene tube is passed through a nostril to the rumen and the catheter is attached to the lower end. The catheter is then pulled up into the lower part of the oesophagus and the polyethylene tube is fastened to a clamp on the horn or halter of the animal. Inflation of the catheter and aspiration of the saliva are performed through additional tubes running through the fistula. An unimpeded flow of air down the polyethylene tube and through the catheter facilitates quantitative collection of saliva.

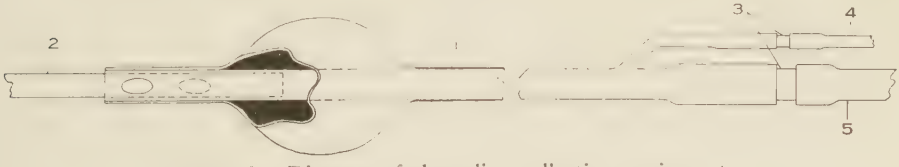

Figure 2. Diagram of the saliva collection equipment.

1. 100 ml. size 22, inflatable rubber catheter. A $\frac{1}{8}''$ diameter hole is bored in the rounded tip to permit insertion of the polyethylene tube 2.
2. Polyethylene tubing: 7′, $\frac{1}{8}''$, $\frac{1}{16}''$. Openings are cut to correspond with those of the catheter.
3. Polyethylene couplings: 2″, $\frac{1}{8}''$, $\frac{1}{16}''$ and 2″, $\frac{5}{32}''$, $\frac{1}{16}''$.
4. Rubber inflation tube for bulb of catheter: 2″, $\frac{1}{8}''$, $\frac{1}{16}''$.
5. Rubber saliva collection tube running to a suction flask: 5′, 3/16″, 3/32″.

[1] Contribution No. 399, Chemistry Division, Science Service, Canada Department of Agriculture, Ottawa, Ont.

Both pieces of equipment are at present being used in studies on the digestion and absorption of various materials in the reticulo-rumen. Results of these studies will appear in a later publication.

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A FEEDLOT STUDY OF BISON, CATTALO AND HEREFORD CALVES[1]

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ABSTRACT

Time-constant feedlot experiments were conducted in 1952-53 and 1956-57 with bison, Cattalo and Hereford bull and heifer calves at the Canada Range Experimental Farm, Manyberries, Alberta. The Cattalo made significantly greater feedlot gains than bison and lower gains than Herefords in both experiments. There was a significant reduction in carcass grade, a reduction in proportion of carcass weight in the hind quarters, and an increase in dressing percentage as the proportion of bison breeding increased.

INTRODUCTION

In order to properly assess the beef-producing potential of Cattalo, information was needed on the feedlot performance and carcass quality of Cattalo and of the parental types, bison (Bison Americanus) and domestic beef cattle (Bos taurus).

Logan and Sylvestre (1) reported that Hereford steer calves made greater and more efficient feedlot gains than Cattalo in an experiment conducted at the Manyberries Experimental Farm in 1949-50. On the basis of an evaluation of Cattalo and Hereford carcasses in that experiment, it was concluded that no difficulty should be experienced in marketing Cattalo beef.

Further experiments were undertaken in 1952-53 and 1956-57 to obtain comparative data on the rate and efficiency of gain, carcass grade, dressing percentage and proportion of carcass weight in the hind-quarters of bison, Cattalo and Hereford calves. The results are given in this report.

MATERIALS AND METHODS

Cattalo and grade Hereford calves raised on the Manyberries Farm and bison calves from Elk Island Park, Lamont, Alberta, were selected for these experiments. The Cattalo calves out of first cross, domestic × bison, cows were separated from the Cattalo calves out of backcross (to domestic) and inter-bred Cattalo cows. The term "inter-bred" refers, in this paper, to offspring of Cattalo × Cattalo matings; these animals were approximately ¾- to ⅞-domestic in breeding. Male (entire) and female calves were fed in separate groups within breed types.

Following a preliminary feeding period of 2 weeks, experimental feeding began on January 7 in 1953 and on December 30 in 1956. Feeding was continued each year until the Herefords were judged to be finished (196 days in the first experiment and 197 days in the second). Self-feeders were used for the grain part of the ration, which consisted of oats in the early part of the feeding period and was gradually changed to a mixture of

[1] Contribution from the Division of Animal Husbandry, Experimental Farms Service.

TABLE 1.—FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS OF BISON, CATTALO AND HEREFORD CALVES, 1952-53 AND 1956-57

	Experiment number	Male				Female			
		Bison	Cattalo[1]		Hereford	Bison	Cattalo[1]		Hereford
			(H)	(BI)			(H)	(BI)	
No. of animals completing feedlot test	*1	9	7	5	11	8	12	5	10
	*2	8	5	11	10	11	12	12	10
Av. initial weight (lb.)	1	343	433	396	371	331	410	364	382
	2	377	450	434	388	366	430	384	375
Av. daily gain (lb.)	1	1.4	1.9	1.9	2.0	1.1	1.5	1.5	1.8
	2	1.1	1.8	2.2	2.4	0.9	1.6	1.9	2.1
Av. daily feed intake (lb.): Hay	1	3.1	3.4	3.6	3.5	3.7	3.0	3.8	4.2
Grain	1	9.0	11.8	12.2	11.5	9.5	10.3	11.0	11.6
Hay	2	2.9	4.3	4.9	4.7	2.7	4.8	4.6	4.6
Grain	2	8.7	12.6	12.8	12.6	8.0	11.3	11.5	12.3
T.D.N./cwt. gain (lb.)	1	594	554	576	496	787	601	640	578
	2	700	621	530	477	831	647	567	534
No. of carcasses studied	1	4	4	0	4	4	4	0	4
	2	8	5	9	10	11	12	12	10
Av. % shrinkage in transit	1	2.0	6.0		5.8	4.1	8.7		5.1
	2	0.7	3.3	4.1	3.1	1.2	1.6	3.8	4.8
Av. dressing %	1	60.1	62.2		59.8	61.7	61.9		58.
	2	60.1	60.6	59.0	58.5	59.8	57.3	57.1	56.1
Av. carcass grade[2]	1	S	Low C		Dl	M	B		A
	2	S	S	S	S	Dl	C	B	A
Av. % of carcass weight in hind-quarters	1	46.1	46.0		48.2	47.6	48.2		49.3
	2	46.8	47.0	46.9	47.8	47.5	48.5	49.7	50.4

[1](H)-Cattalo out of hybrid cows and (BI)-Cattalo out of backcross and inter-bred cows
[2]A-Choice, B-Good, C-Commercial, Dl-Utility, M-Canners and Cutters, S-Bully
*1952-53 and 1956-57, respectively

⅔ ground barley and ⅓ ground oats, by weight. All calves received a daily allowance of ¼- to ½- pound of linseed oilcake per head throughout the feeding period. Roughage consisting of ⅔ grass, ⅓ alfalfa hay, was fed free choice. Salt and bonemeal were available in separate boxes, but only trace amounts of bonemeal were consumed. No chemical analysis was made of the feeds used.

Arrangements could be made for only limited handling of carcasses for appraisal in 1953, so only the 4 animals nearest the group average in final weight were selected from each group for carcass appraisal. The groups of Cattalo calves out of backcross and inter-bred cows were omitted from this part of the study. In 1957, all animals except 2 Cattalo bulls that appeared fertile by semen evaluation and had made high gains in the feedlot, were included in the carcass test. Dressing percentage (based on 24-hour chilled carcass weight and live weight at Calgary, after trucking about 250 miles from Manyberries), carcass grade, and percentage of carcass weight in the hind-quarters, as determined by weights of the quarters on the right side, were recorded. In separating the quarters, two ribs were left on each hind-quarter.

RESULTS AND DISCUSSION

Feedlot Gain and Efficiency of Feed Utilization

Analysis indicated a non-significant regression of 0.1 pound of feedlot gain per pound of difference in initial weight of calves. The correlation coefficient was 0.117. There was no evidence of heterogeneity of regression between lots. Analysis of variance was then performed on feedlot gains without adjustment of gains for initial weight (Table 1).

In the first experiment, there was no significant difference between the gains of Cattalo out of hybrid cows and those of Cattalo out of backcross and inter-bred cows. The Herefords gained, on the average, 48 lb. more than the Cattalo and 138 lb. more than the bison ($P < 0.01$). In the second experiment, the two Cattalo types differed significantly in feedlot gain ($P < 0.01$). Herefords gained, on the average, 45 lb. more than Cattalo out of backcross and inter-bred cows, 102 lb. more than Cattalo out of hybrid cows, and 250 lb. more than bison ($P < 0.01$).

The ranges in average daily gain for the calves fed in 1956-57 were as follows: bison bulls, 0.9 to 1.4 lb.; bison heifers, 0.5 to 1.1 lb.; Cattalo bulls, 1.8 to 2.8 lb.; Cattalo heifers, 1.4 to 2.2 lb.; Hereford bulls, 2.1 to 2.7 lb.; and Hereford heifers, 1.7 to 2.4 lb. The only bison that approached the other cattle in rate of gain was a bull that gained 2 lb. per day in the first experiment.

There was no evidence of significant seasonal trend in rate of gain in any of the breed groups.

In both experiments, the bison were least efficient and the Herefords were most efficient in terms of T.D.N. (total digestible nutrients) utilized per pound of gain.

Carcass Grade, Dressing Percentage and Percentage of Carcass Weight in Hind-Quarters

In so far as the bulls were concerned, little difference between breeds was shown in carcass grade, as most of these animals graded "staggy" or

"bully". However, significant ($P < 0.01$) breed differences were shown in the heifer grades. Progressively lower grades were obtained as the proportion of bison breeding increased. A lower degree of finish and a higher proportion of carcass weight in the front-quarters were given as the reasons for the lower market grades of the Cattalo and bison*. Nevertheless, one of the 4 Cattalo heifers marketed in 1953 and 4 of the 24 Cattalo heifers marketed in 1957 did grade A in carcass.

Within breeds there was a non-significant regression of carcass grade on live weight. Comparisons between Cattalo and Herefords indicated that at equivalent weights the Herefords had higher carcass grades.

Average ages at slaughter were 455 and 457 days for the Cattalo and Herefords, respectively. The exact ages of the bison were not known but it is unlikely that they differed greatly from the Cattalo and Herefords as the calving season for the bison was about the same as for the Cattalo and Herefords.

There was a general increase in dressing percentage as the proportion of bison breeding increased. The bison did not differ significantly from the Cattalo out of hybrid cows, but they dressed significantly ($P < 0.01$) higher than the other groups. The Cattalo out of hybrid cows exceeded the Herefords significantly ($P < 0.01$) in dressing percentage. No data were obtained in the current experiments on factors affecting dressing percentage, but data obtained in the experiment reported by Logan and Sylvestre (1) indicated that Herefords had heavier hides and viscera than Cattalo in relation to their body weights.

The bison have a high spinal process in the thoracic region and for this reason the hind-quarters appear small in relation to the front-quarters. However, the chine of the bison is narrow, in contrast to that of domestic beef cattle, so that the proportion of carcass weight in the hind-quarters of bison is not as small as might be expected. As shown in Table 1, the proportion of carcass weight in the hind-quarters did increase slightly as the proportion of domestic beef breeding increased. The breed differences were statistically significant ($P < 0.05$).

The results of these experiments indicate that bison do not compare favourably with Herefords in feedlot performance. However, there appears to be enough variation in the Cattalo to permit improvement through selection for gaining ability.

ACKNOWLEDGEMENTS

The co-operation of B. I. Love, Superintendent of Elk Island Park, Lamont, Alberta, in making bison calves available for this project, and the assistance of officials of the Marketing Service, Canada Department of Agriculture, in providing the carcass appraisal, are acknowledged. The feedlot studies were conducted under the supervision of A. A. Ingram, Cattle Herdsman at the Manyberries, Alberta, Range Experimental Farm.

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EFFECTS OF CERTAIN SUPPLEMENTS AND METHODS OF FEEDING DURING LATE PREGNANCY ON LAMB AND WOOL PRODUCTION OF MATURE EWES[1]

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ABSTRACT

A 3-year study compared the effects on lamb and wool production of methods of feeding different supplements to ewes during the last 6 to 9 weeks of pregnancy. The four treatments were: 0.56 lb. barley and 3.5 lb. hay per head daily; 0.5 lb. linseed oilcake and 3.5 lb. hay per head daily; 3.5 lb. linseed oilcake and 24.5 lb. hay per head once weekly; 3.5 lb. hay per head daily.

No significant treatment differences in birth weight of single lambs were found. However, the ewes fed linseed oilcake gave birth to heavier twin lambs than the ewes receiving no supplement ($P<0.01$). There were no significant treatment differences in weaning weight of single or twin lambs, although the average weaning weights of the lambs in the supplemented groups were slightly higher than those in the control group. Of the ewes giving birth to twin lambs, those receiving linseed oilcake daily weaned more pounds of lamb than the control ewes ($P<0.05$).

The ewes supplemented with linseed oilcake produced more grease wool and lost less body weight than the control group ($P<0.01$). There were no significant treatment differences in clean fleece weight.

Weekly feeding offers some possibilities, either as a method of saving labour or as a means of supplying supplement to ewes when deep snow or cold weather prevents grazing.

INTRODUCTION

In the management of pregnant ewes for maximum lamb and wool production under winter range conditions in Western Canada, provision of a balanced and economical ration is essential. Normally, some winter grazing in certain areas is possible because snow cover is removed periodically by the warm Chinook winds. Although the cured native forage has a sufficiently high nutritive content for maintenance, some supplemental feeding is necessary to provide an adequate plane of nutrition for pregnant ewes.

Numerous workers have shown (6, 10, 12, 13, 15) that supplemental feeding of concentrates or the feeding of legume hay to ewes in late pregnancy resulted in heavier and more vigorous lambs at birth and lower post-natal mortalities of lambs than when non-leguminous roughage was fed alone throughout pregnancy. Others (2, 11) found no effect on birth weight or growth rate of lambs when pregnant ewes were fed a concentrate during late pregnancy. Post-natal mortalities, however, were less. Results at the Range Experimental Farm, Manyberries, Alberta (7) indicated that it was not economical to feed concentrates throughout pregnancy when non-legume hay containing 8 per cent of crude protein was fed.

[1] Contribution from Division of Animal Husbandry, Experimental Farms Service, Ottawa, Canada.
[2] Range Experimental Farm, Manyberries, Alberta.
[3] Experimental Farm, Lethbridge, Alberta.

In Australia, studies by Franklin (3, 4) favoured twice-weekly feeding rather than daily feeding of sheep, when drought or comparable stress conditions existed. In those experiments weekly feeding appeared to be satisfactory when the fasting period did not exceed $2\frac{1}{2}$ to 3 days.

It would appear that further information on the use of certain concentrates for supplemental feeding of ewes during late pregnancy and on methods of feeding to reduce labour costs is needed. This paper reports the results of a 3-year project at the Range Experimental Farm, Manyberries, Alberta, to study the effects of certain supplements and methods of feeding on lamb and wool production of mature range ewes.

PROCEDURE

Each year, 100 ewes of Romnelet breeding were selected and allotted equally to four treatments on the basis of age, weight, condition, and sire group. The treatments were as follows:

Lot 1—0.56 lb. barley and 3.5 lb. grass hay per head daily

Lot 2—0.5 lb. linseed oilcake and 3.5 lb. grass hay per head daily

Lot 3—3.5 lb. linseed oilcake and 24.5 lb. grass hay per head fed once weekly

Lot 4—3.5 lb. grass hay per head daily.

The daily allowance of 0.56 lb. of barley equalled 0.50 lb. of linseed oilcake in energy value.

Prior to each year's test, the experimental flock was run with the main band and pre-test management was similar each year. During this period the ewes grazed native range typical of the mixed grass prairie described by Coupland (1).

In 1952, the experimental ewes were fed supplements and/or hay in pens from March 4 to April 16, inclusive. From April 17 to 23, grazing replaced the hay for all groups but concentrates were fed to Lots 1, 2 and 3. In 1953, pen feeding began on March 3 and continued till May 3. From May 4 to 8 the ewes received their supplements but grazed on the range. During the 1954 trial, pen feeding continued from March 1 to May 2, inclusive. The ewes were removed from the experiment as they lambed.

Salt and bonemeal were fed *ad libitum* and water was provided at least twice daily. Crested wheatgrass hay was fed during the first 26 days of the trial in 1952, after which slough hay was fed. Crested wheatgrass hay was fed throughout the trials in 1953 and 1954.

All lambs were weighed and graded within 24 hours of birth. They were scored on vigour and strength by the procedure of Williams *et al.* (15). Weaning weights of all lambs were recorded. All ewes were weighed at the beginning of the trial and were weighed and scored for condition and milk supply within 24 hours after lambing. Grease fleece weights were obtained from all ewes at shearing. Representative wool samples were analysed for clean fleece weight, stable length, and fibre thickness.

TABLE 1.—LAMB PRODUCTION OF EWES AS INFLUENCED BY SUPPLEMENTAL FEEDING, 1952-54

Lamb data		Supplement			
		Barley	Linseed oilcake		None
			Daily	Weekly	
No. lambs born		93	93	98	94
Lambs grading "good"	%	80	85	84	79
Av. birth wt.					
Singles	no.	50	43	49	48
	lb.	9.4	10.0	10.1	9.4
Twins	no.	35	42	41	39
	lb.	7.8	8.5[1]	8.1[1]	7.4
Av. weaning wt.					
Singles	no.	42	39	44	44
	lb.	63.1	65.0	65.3	62.1
Twins raised as twins	no.	20	34	24	20
	lb.	62.1	63.0	61.3	59.0
Mortality—birth to weaning					
Singles	%	18	20	12	12
Twins	%	33	14	29	36
Pounds of lamb weaned per ewe with:					
Singles		51.6	51.6	57.5	54.8
Twins		84.1	106.1[2]	85.7	72.7
All lambs		61.0	68.5	66.6	60.2

[1] Significantly heavier than the control group ($P < 0.01$)
[2] Significantly more than the control group ($P < 0.05$)

RESULTS AND DISCUSSION

Birth Weights of Lambs

A summary of the lamb production data obtained during the years 1952 to 1954, inclusive, is presented in Table 1.

An analysis of variance indicated that there were significient ($P < 0.01$) treatment differences in birth weight of twin lambs and year differences in birth weight of single lambs. The ewes receiving the linseed oilcake supplement daily or weekly gave birth to heavier twin lambs than those receiving barley or no supplement. It also was observed that a greater proportion of the lambs born to ewes in the linseed oilcake supplemented group were graded good in condition and vigour.

The digestible protein and T.D.N. intake (6) of the ewes supplemented with linseed oilcake or barley (Table 2) closely approximated or exceeded the N.R.C. requirements for pregnant animals (8). The T.D.N. intake of the control ewes was below the required amount, but they received an adequate level of protein. Consequently, this could account for the fact that no significant differences were obtained in the birth weights of single lambs. However, the additional digestible protein in the oilcake rations, as compared to the barley and control rations, probably was responsible for the significant increase in the birth weights of twins. This indicates that the protein requirement of ewes carrying twin lambs was

TABLE 2.—AVERAGE DAILY DIGESTIBLE PROTEIN AND TOTAL DIGESTIBLE NUTRIENT INTAKE BY EWES ON THE SUPPLEMENTAL FEEDING TRIAL, 1952-54

Year	Nutrient	Supplement (lb.)				N.R.C. recommended requirements(8) (lb.)
		Barley	Linseed oilcake		None	
			Daily	Weekly		
1952	Digestible protein	0.24	0.36	0.35	0.18	0.20
	T.D.N.	2.45	2.39	2.31	1.96	2.40
1953	Digestible protein	0.28	0.38	0.39	0.21	0.20
	T.D.N.	2.37	2.31	2.36	1.82	2.40
1954	Digestible protein	0.26	0.38	0.39	0.23	0.20
	T.D.N.	2.36	2.37	2.40	1.95	2.40

TABLE 3.—AVERAGE BODY WEIGHTS, CONDITION AND MILK SUPPLY SCORES, AND FLEECE CHARACTERISTICS OF EWES AS INFLUENCED BY SUPPLEMENTAL FEEDING, 1952-54

Ewe data		Supplement			
		Barley	Linseed oilcake		None
			Daily	Weekly	
No. of ewes		72	71	74	72
Av. wt. of ewes	lb.				
Initial weight		130.7	131.8	129.9	133.1
After lambing		118.6	123.2	121.5	116.4
Loss in weight		12.1	8.6[1]	8.4[1]	16.7
Condition grade of ewes at lambing	%				
"Good"		94	90	90	79
"Fair"		6	10	10	11
"Poor"		0	0	0	10
Milk supply score	%				
"Good"		86	87	79	69
"Fair"		14	13	20	18
"Poor"		0	0	1	13
Av. wool production					
Grease fleece wt.	lb.	8.6	9.1[2]	9.0[2]	8.6
Clean fleece wt.	lb.	5.0	5.2	5.1	4.9
Staple length	mm.	87	86	90	87
Fibre thickness	μ	28.0	28.5	28.5	28.1

[1] Significantly less than the control group ($P < 0.01$)
[2] Significantly heavier than the control group ($P < 0.01$)

greater than that of ewes carrying singles. There were only small differences in digestible protein and T.D.N. between years and consequently the year differences in weights of singles must have resulted from other factors.

Weaning Weights

The average age of the lambs at weaning was 154.4 days. The weaning weights were adjusted to the age of 154 days by the analysis of covariance. The regression coefficients of age on weaning weight were found to be 0.34, 0.32 and 0.17 lb. for 1952, 1953 and 1954, respectively. No heterogeneity of regression was obtained between sexes or between singles, twins raised singly, or twins raised as twins and consequently the data were combined within years. The average weaning weights of lambs born to ewes on the various treatments are presented in Table 1.

Weaning weights were adjusted for sex differences by employing the constants developed by MacNaughton (5). Separate constants were calculated by sex for singles and twins raised as twins to adjust all weaning weights to a female, single-lamb basis. Although there were no significant treatment differences in weaning weights of single or twin lambs, significant year differences ($P<0.01$) in these weaning weights occurred in each group.

Lamb Production per Ewe

Ewes receiving the daily ration of linseed oilcake and giving birth to twin lambs weaned significantly ($P<0.05$) more lb. lamb per ewe than the control ewes receiving no supplement (Table 1). This was due to the greater survival of twin lambs from birth to weaning in the supplemented group. There was no significant difference in pounds of lamb weaned per ewe by ewes giving birth to single lambs.

Wool Production

A summary of the average wool production obtained from the ewes on the various treatments is shown in Table 3.

There were significant treatment differences ($P<0.01$) in average grease fleece weights. Ewes receiving linseed oilcake as a supplement, by either method of feeding, produced more grease wool than those receiving barley or no supplement. When considered on the basis of clean fleece weight a small non-significant increase was obtained from oilcake feeding when compared with the control group. Results obtained by Whiting *et al.* (14) showed that higher levels of nutrition increased the amount of fleece impurities. This could account for the significant treatment differences that were obtained in the grease weights. No differences in average staple length or fibre thickness were obtained in this study.

Body Weight and Grade Score of Ewes

Table 3 summarizes the average ewe body weight and condition and milk supply scores at lambing. There were significant year and treatment differences ($P<0.01$) in body weight losses. The majority of body weight losses were in 1952 as the weather conditions were most severe in

that year. During the 3-year period ewes supplemented with linseed oilcake lost less body weight than those receiving barley or no supplement.

A greater proportion of the supplemented ewes were scored as "good" in condition and milk supply at lambing than was the case in the control group.

The ewes receiving the weekly ration of linseed oilcake and hay were equal to the daily-fed oilcake group in weight maintenance during the period of feeding and no digestive disturbances were observed. The weekly-fed ewes always consumed their ration of linseed oilcake within 2 or 3 days, but it took 5 to 6 days to consume the hay. This manner of feeding ewes offers possibilities either as a labour-saving method or as a means of supplying supplement during periods when grazing is impossible owing to deep snow or cold weather. However, as Australian (3, 4) studies have indicated, if any ration is so readily consumed that a fasting period of more than 2 or 3 days occurs, then feeding more frequently than once a week may yield better results.

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STUDIES ON THE NUTRITIVE VALUE OF REFUSE SCREENINGS

I. THE ESSENTIAL AMINO ACID CONTENT OF CERTAIN WEED SEEDS[1]

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ABSTRACT

The essential amino acid content of a number of the weed seeds found in refuse screenings is reported. In terms of nutritive value the weed seed proteins are comparable with those contained in soybean, flax and rape seed. The results reported lend support to the view that properly processed refuse screenings is a satisfactory feeding stuff for the ruminant animal.

INTRODUCTION

For a number of years, heat devitalized refuse screenings have been used as a feed for ruminant animals in British Columbia and several of the western states of the United States. To date, more than 60,000 tons of the processed material have been fed successfully to beef cattle. Certain of the weed seeds in refuse screenings are considered as harmful and a number of regulations control their sale and use. Information on the toxicity and nutritive value of these weed seeds is needed to permit adequate evaluation of refuse screenings as a livestock feed.

The present paper records the essential amino acid content of a number of the weed seeds normally present in appreciable amounts in refuse screenings.

MATERIALS AND METHODS

Source of Seed Samples

The samples of weed seeds were supplied by the Plant Products Division, Production Service, Canada Department of Agriculture. The sample of Argentine rape seed was obtained from D. R. Clandinin, the University of Alberta, Edmonton, Alta., while the samples of soybean and flax seed were obtained from Buckerfields Ltd., Vancouver, B.C. Analyses of the latter three seeds and a sample of casein[4] were included to permit comparison of the analytical values reported here with those reported elsewhere for these materials.

Preparation of Materials

All seed samples were ground in a hammer mill. The lipids were removed by Soxhlet extraction for 16 hours with petroleum ether. The petroleum ether extracted residue was dried and further ground to pass a .040″ screen.

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Hydrolysates of the samples were prepared according to the procedures outlined by Barton-Wright (3). For the assay of tryptophane, enzymatic hydrolysis with pepsin*, trypsin* and erepsin* was carried out. For the assay of tyrosine, alkaline hydrolysates were used (5 N NaOH for 8 hours at 15 lb. pressure). Acid hydrolysates used for the determination of the other amino acids were prepared by suspending 1 gram of sample in 25 ml. of 2.5 N HCl and autoclaving at 15 lb. pressure for 6 to 10 hours. Any ether extractives released during hydrolysis were removed by shaking the hydrolysates with ethyl ether in a separatory funnel as recommended by Barton-Wright (3).

Methods of Analysis

The microbiological assay procedures described by Barton-Wright (3) were followed for the determination of the amino acid content of the hydrolysates. The assay organisms used were:

Lactobacillus arabinosus	17-5	(8014†)
Leuconostoc mesenteroides	P-60	(8042†)
Streptococcus faecalis	(lactis Rogers)	(8043†)

The procedures followed for the culture of these organisms and for the preparation of the assay inocula were essentially those described by Barton-Wright (3).

For each amino acid, hydrolysates were assayed at five concentration levels (usually 500 mg. to 2500 mg. of original sample). All concentration levels of the standard solutions and extracts were set up in triplicate. For the standard curves DL-forms of phenylalanine, iso-leucine, valine and threonine were used. The natural isomers of the other amino acids were used.

After addition of the inoculum, the tubes were incubated in a constant temperature water bath at 30° C. for 72 hours. The lactic acid present at the end of this time was estimated by electrometric titration against 0.1 N NaOH to pH 7.0.

Standard dose-response curves for each of the amino acids were prepared by plotting the logarithm of amino acid concentration against the growth response expressed in terms of the volume of 0.1 N NaOH required to neutralize the lactic acid produced (3). The amino acid equivalence of each of the five levels of each hydrolysate was determined by reference to the appropriate standard curve. The mean value and standard deviation were computed for each sample.

RESULTS

Analyses for the total crude protein (Nx 6.25) and ether soluble material were performed on all of the seed samples. The nitrogen determinations were carried out on both the ground raw and petroleum ether extracted samples. The values given in Table I for the protein and fat content of the casein, soybean and linseed samples are within the ranges established for these feedstuffs.

* General Biochemicals, Inc.
† American Type Culture Number.

TABLE 1.—PER CENT CRUDE PROTEIN AND PETROLEUM ETHER EXTRACT IN WEED SEEDS

	Crude protein (N × 6.25)		Ether extract
	Ground raw seed	Ether extracted seed	
Brown mustard (*Brassica juncea L. Cross*)	22.9	37.1	38.3
Stinkweed (*Thlaspi arvense L.*)	16.0	23.7	33.0
Tumble mustard (*Sisymbrium altissimum L.*)	32.7	41.1	20.5
Western false flax (*Camelina microcarpa Andra*)	22.6	36.8	38.7
White mustard (*Brassica alba Boiss*)	28.0	40.2	30.5
Wild mustard (*Brassica kaber (DC) L. C. Wheeler*)	27.4	37.5	27.1
Casein	86.3	—	—
Soybean (*Glycine soya*)	38.0	48.2	21.3
Linseed (*Linum usitalissium*)	22.0	36.5	39.7
Rape seed (*Brassica napus L.*)	28.5	44.6	36.2

Table 2 shows that acceptable values were obtained for 10 of the amino acids in casein, soybean and linseed oil meal and that comparable values were obtained for the same amino acids in the weed seed proteins. Satisfactory results were not obtained with Barton-Wright's procedure (3) for cystine and tyrosine.

It is possible to assess the accuracy of the amino acid estimates in a number of ways from the data obtained in the analyses. According to Yemm and Folkes (8), the reliability of a microbiological assay is indicated by the degree of agreement between the estimates based on the five levels of protein hydrolysate, each the mean of three tests. In a satisfactory assay these estimates agree closely and do not change systematically with increasing protein level. In a number of the assays an enhanced response appeared at the lowest concentration of the protein hydrolysate. In the cases where this occurred these values were omitted in the calculation of the mean value. All the assay results quoted in Table 2 are derived from assays in which the maximum deviation from the mean of the four or five estimates is less than 10 per cent of the mean value. The values for the standard deviations given in Table 2 also indicate the degree of uniformity between the estimates.

The uniformity of the slopes of the standard and test curves when plotted on a log-log basis, according to Barton-Wright (3), indicated the assays were valid. In view of the variations which are known to occur between samples and between the procedures of different laboratories the data reported here are in good agreement with those reported elsewhere. (4, 5).

TABLE 2.—GRAMS AMINO ACID PER 16 GM. PROTEIN NITROGEN IN WEED SEEDS

Amino Acid	Casein	Soybean	Linseed	Rape seed	Brown mustard	Stinkweed	Tumble mustard	Western false flax	White mustard	Wild mustard
Nitrogen*	13.62	7.71	5.85	7.14	5.94	3.79	6.59	5.89	6.43	6.00
Arginine	3.8±0.2	7.7±0.3	7.7±0.7	6.1±0.9	6.4±0.5	6.3±0.1	7.1±0.4	7.3±0.4	5.2±0.3	6.6±0.4
Histidine	2.7±0.2	2.4±0.2	1.6±0.1	2.4±0.1	2.4±0.2	1.8±0.1	2.1±0.1	2.0±0.1	2.6±0.3	2.4±0.05
Leucine	8.7±0.2	6.4±0.1	4.6±0.3	5.7±0.1	5.2±0.04	6.0±0.4	5.9±0.4	5.2±0.2	5.6±0.05	5.3±0.2
Iso-Leucine	6.4±0.2	5.0±0.1	4.5±0.1	4.4±0.1	4.2±0.2	4.2±0.4	4.3±0.3	4.4±0.4	4.0±0.03	3.8±0.1
Lysine	9.3±0.4	6.1±0.3	3.6±0.3	5.2±0.2	5.6±0.1	5.6±0.5	4.2±0.2	4.5±0.6	6.0±0.4	5.1±0.2
Methionine	3.1±0.3	1.3±0.1	1.5±0.1	1.9±0.2	1.6±0.1	1.3±0.3	1.5±0.02	1.2±0.05	1.5±0.03	1.4±0.05
Phenylalanine	4.4±0.5	3.9±0.3	3.1±0.3	3.1±0.2	2.8±0.3	2.9±0.4	3.3±0.2	3.2±0.4	3.0±0.2	3.0±0.3
Threonine	4.2±0.5	3.1±0.2	2.8±0.2	3.1±0.2	3.0±0.2	3.5±0.3	3.3±0.2	3.0±0.2	3.3±0.3	2.8±0.2
Tryptophane	2.2±0.3	1.5±0.1	2.0±0.1	1.3±0.1	1.1±0.1	1.0±0.1	1.3±0.2	1.3±0.1	0.7±0.07	0.8±0.1
Valine	6.7±0.4	4.7±0.2	4.4±0.3	4.5±0.04	4.2±0.3	4.4±0.3	4.2±0.3	4.5±0.2	4.5±0.3	4.2±0.2

* Nitrogen—gm. per 100 gm. fat-free sample

DISCUSSION AND CONCLUSION

Consideration of the crude protein determinations reported in Table 2 indicates that the weed seeds under study offer a relatively promising source of nitrogen for animal consumption. With the exception of stinkweed, these weed seeds are comparable in nitrogen content to linseed and soybean.

The results of the amino acid analyses presented in Table 2 indicate that the amino acid content of the weed seeds tends to follow the general pattern found in rape seed (*Brassica napus* L.). This is not surprising, since all the weed seeds studied are classified, with rape seed, in the family Cruciferae (7). A number of the weed seeds also belong to the same genus *Brassica* as does rape seed. White mustard (*Brassica alba* Boiss) and wild mustard (*Brassica kaber* (DC) L. C. Wheeler) tend to be lower in tryptophane content than the other seeds analysed, while stinkweed (*Thlapsi arvense* L.) is lower in histidine. The essential amino acid content of the weed seeds compares favourably with the general pattern found in soybean.

Methionine and cystine are usually the limiting amino acids in the plant proteins. The values found for methionine in the weed seeds are comparable to that for soybean and are higher in some cases, viz. brown mustard (*Brassica juncea* L. Coss),tumble mustard (*Sisymbrium altissimum* L.) and white mustard (*Brassica alba* Boiss). Following the suggestion of Mitchell (6), "chemical scores" or "modified essential amino acid indices" calculated for the weed seed proteins confirmed that methionine is the limiting amino acid for optimal animal growth.

In conclusion, it would appear that these weed seeds offer a satisfactory source of protein for ruminants and for monogastric animals, provided feeds for the latter are supplemented with suitable sources of the sulphur containing amino acids. The above conclusion must, of course, be tempered to a degree by the knowledge that these weed seeds, like rape seed, contain levels of thiocyanates which might make them suspect as protein sources. This may not be too important for ruminants, because many thousands of tons of refuse screenings containing these weed seeds have been fed successfully to ruminant animals.

TABLE 3.—AMINO ACID CONTENT REPORTED FOR FOUR PROTEIN SUPPLEMENTS
(Gm. per 16 gm. Nitrogen)

Amino acid	Casein				Soybean				Linseed				Rape seed	
Reference No.	PR*	(5)	(5)	(8)	PR*	(5)	(5)	(4)	PR*	(1)	(5)	(4)	PR*	(2)
Arginine	3.8	4.2	3.7	4.1	7.7	—	3.4	5.8	7.7	9.9	9.5	6.9	6.1	5.6
Histidine	2.7	3.2	3.0	2.5	2.4	—	1.1	2.3	1.6	2.7	1.8	1.9	2.4	2.6
Leucine	8.7	9.4	10.5	9.9	6.4	5.1	3.8	6.6	4.6	6.3	6.4	7.5	5.7	5.7
Iso-Leucine	6.4	6.2	7.1	6.5	5.0	—	2.4	4.7	4.5	5.6	4.1	3.4	4.4	3.7
Lysine	9.3	8.4	7.7	7.9	6.1	6.6	1.8	5.8	3.6	3.5	3.3	2.0	5.2	3.5
Methionine	3.1	2.9	3.1	3.4	1.3	1.4	0.5	2.0	1.5	1.5	1.2	2.3	1.9	1.1
Phenylalanine	4.4	5.1	5.1	5.2	3.9	5.1	2.5	5.7	3.1	3.9	4.6	5.8	3.1	4.0
Threonine	4.2	5.0	4.6	3.9	3.1	3.8	1.9	4.0	2.8	3.9	4.2	4.5	3.1	3.8
Tryptophane	2.2	1.2	1.4	1.3	1.5	1.3	0.5	1.6	2.0	1.4	1.3	1.6	1.3	2.0
Valine	6.7	7.4	6.3	7.0	4.7	5.4	2.6	4.2	4.4	5.9	4.7	5.8	4.5	5.7

*PR—Present results

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